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SOIL DRIFTING CONTROL
IN THE
PRAIRIE PROVINCES

BY

E. S. HOPKINS, A. E. PALMER
and W. S. CHEPIL

DIVISION OF FIELD HUSBANDRY
EXPERIMENTAL FARMS SERVICE

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ACKNOWLEDGMENT

The authors wish to acknowledge the very helpful assistance, in the preparation of this bulletin, of the staffs of the various Dominion Experimental Farms in the Prairie Provinces.

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This method of summerfallowing should be discontinued. Large fields of summerfallow, with the surface soil worked down to a fine condition, promote soil drifting. The field should be stripped in narrow bands of crop and summerfallow and should be cultivated so as to leave stubble at the surface or a cloddy surface soil.

SOIL DRIFTING CONTROL IN THE PRAIRIE PROVINCES

In some of the earliest reports of the Dominion Experimental Farms reference is made to the occurence of soil drifting. Even as early as 1887 severe drifting was experienced on the experimental farm at Indian Head and throughout that district. Soil drifting is not of recent origin, therefore, but appears to have developed soon after the prairie lands were broken and seeded to grain. About 1918 determined efforts to control drifting were commenced in the Monarch district of southern Alberta. These efforts have met with such decided success that this district is now regarded as the most outstanding example in Canada of successful control even in an area where severe drifting is likely to occur almost every year. More recently, similar methods have been adopted in a few other districts, chiefly as a result of united action by groups of farmers. Over the greater part of the Prairie Provinces, however, the intermittent occurrence of drifting from year to year, and the more or less widely separated areas involved, have probably discouraged any extensive attack on the problem. During the years from 1931 to 1938, however, soil drifting assumed such serious and widespread proportions and caused such tremendous damage to farm property that more definite action towards effective and permanent control became imperative. This bulletin presents detailed information outlining the most successful methods now known of controlling drifting.

AREA INVOLVED

Few areas on the prairie are entirely immune from soil drifting. Wherever there is bare soil and the necessary combination of predisposing causes exists, more or less serious drifting may be expected unless some control measure is adopted. In this regard the practice of summerfallowing, essential over the greater part of the prairie for the conservation of moisture, provides large areas of bare land. Approximately 19,782,000 acres of land were summerfallowed in 1944 in the three Prairie Provinces out of a total cultivated area of 67,095,016 acres. Grain crops comprised 41,718,000 acres and constituted the principal type of crop grown in the three Prairie Provinces as will be seen by reference to table 3 of this bulletin.

OCCURRENCE

Observations indicate that extremely light and some of the extremely heavy soils, such as sands and calcareous clays, are more susceptible to drifting than the soils collectively known as loams. In wooded or park areas, with natural protection against wind movement and quite favourable moisture conditions soil drifting is relatively infrequent but on occasions has been serious. On the other hand, the open plains, which permit the unhindered passage of wind from every direction, constitute the areas most frequently affected. Even here conditions vary from one locality to another. Generally speaking southern Alberta, southern Saskatchewan and southwestern Manitoba are the areas most susceptible to serious drifting. Elsewhere there may be periods of several years intervening between the occurrence of severe dust storms. Drifting usually occurs during the spring months of April and May and, on occasions, during June. It is not an infrequent occurrence in southern Alberta, even during the winter months.

CAUSES

The obvious cause of soil drifting is the action of wind upon loose, dry soil unprotected by vegetation. Soil drifting is thus more severe during seasons of drought or severe insect damage when vegetation has been destroyed and the soil has been left bare. Studies show, however, that the severe action of high winds upon dry, bare soil is not necessarily a prelude to serious drifting. Many factors are involved, and because some factors may counteract or nullify the influence of the others, the problem is very complex. There are three groups of factors that influence soil drifting—the condition of the air, the ground surface, and the soil.

The severity of soil drifting is only slightly influenced by ordinary changes in air density as affected by changes in temperature, pressure, and humidity. It is markedly affected by velocity and degree of gustiness of the wind. A gusty wind will erode substantially more soil than a uniform wind of exactly the same average velocity.

Atmospheric turbulence increases the velocity and gustiness of the wind near the earth's surface and is therefore the primary cause of dust storms in dry regions. The degree of turbulence close to the ground, however, is determined mainly by the condition of the ground surface and not appreciably by atmosphere turbulence. Turbulent flow near the ground is caused by two major eddy forms, frictional eddies caused mainly by air striking against surface obstacles and convectional eddies caused by higher ground than air temperatures.

It may be assumed, since turbulence of wind increases soil drifting, that cultural methods which tend to reduce turbulence would be effective for soil drifting control. However, some of the successful methods of control now in use are based on the principle of placing obstructions in the path of the wind to break its force. The presence of clods, stubble, or bluff obstructions increases turbulence, but the importance of such obstructions lies in the fact that they absorb much of the force of the wind, thus reducing its velocity. One of the main principles of soil drifting control, therefore, is the reduction of wind velocity near the ground.

The convectional eddies increase the surface velocity of the wind and may result in severe cases of soil drifting. The convectional eddies are most likely to occur over bare fallow which absorbs much of the sun's heat. The "lifting" effect of the wind is reduced somewhat by leaving plant residues at the surface of the ground to deflect the sun's rays and by dividing fallow fields in alternate strips of crop and fallow. In strip farming the convectional eddies produced over the heated fallow surfaces are damped down somewhat as they pass over the adjacent cooler strips of crop or stubble.

The velocity of wind is zero among the irregularities of the ground surface but increases rapidly with height above the ground. The velocity of 6 inches is 50 per cent or less of that at 5 feet. The velocity over higher ground such as knolls, is therefore higher than in the lower positions and because even small changes in velocity produce marked changes in the severity of drifting, it is apparent why knolls tend to drift first.

The wind of such velocity as to cause soil drifting is always turbulent and is characterized by eddies and irregularities of movement of extremely variable velocities. The erosive wind is in fact made up of momentary currents blowing in all directions. The upward component of velocity near the ground is, on an average, one-fifth of the forward velocity. Drifting of highly erosive soil usually starts when wind reaches a forward velocity of 11 to 15 miles per hour at one foot height. At this height the upward velocity of eddies is 2 or 3 miles per hour, sufficient to lift a quartz particle of the size of silt. Once lifted off the ground, silt constitutes the bulk of the material carried as dust.

Although dust is readily transported through the atmosphere, it is very resistant to erosion by wind, because of cohesion and other causes. Dust is

Wind tunnels are used to study soil drifting at the Soil Research Laboratory, Dominion Experimental Station, Swift Current, Saskatchewan. The upper photograph shows the tunnel used in the laboratory while below is shown a portable tunnel for use in fields.

lifted into the air not by direct wind pressure but by impacts of the larger, more erosive particles generally of the size of dune sand. Hence the most erosive soils are those composed of fine granules ranging from 0·1 to 0·5mm. in diameter. All highly erosive soils contain more than 60 per cent of this fraction, whereas highly resistant soils contain less than 40 per cent.

Soil granulation in the Prairie Provinces, which is generally excessive as far as wind erosion is concerned, is caused by two major factors—the high content of calcium carbonate, which is commonly known as lime, and the high content of decomposed organic matter. The addition of as little as 2 per cent of powdered calcium carbonate to a highly resistant soil causes disintegration of clods and surface crust to small granules that are highly susceptible to wind erosion.

Decomposed organic matter, often designated as humus, has much the same effect on the physical condition of the soil as lime and often facilitates soil drifting. It gives the surface soil its characteristic black colour and is to some extent indicative of soil fertility. In a sense it induces soil aggregation in that it causes the aggregation of individual silt and clay particles into small granules. This may or may not have an effect on the relative resistance of the soil to wind erosion, the deciding factor being whether the granules formed are sufficiently large to withstand the erosive force of wind. In the majority of cases in the Prairie Provinces, high humus content causes the formation of granules that are generally too small to resist the wind. Some soils with high organic matter, such as the Red River clay, are coarsely granulated and do not drift readily except under exceedingly dry conditions in the spring.

Organic matter in the process of decomposition has been found to be highly inducive of clod formation. This appears to be due to certain mucilaginous substances of bacterial origin. The effects are not permanent, however, because the mucilaginous substances are converted in time to more or less inert humic materials and unless fresh organic matter is added, clod structure will slowly disintegrate to a granulated condition.

Most observers are agreed that newly-broken virgin soil seldom drifts. As long as the fibrous material of the original vegetation is present, this acts as a binder to the soil particles. In the course of time, however, this fibrous material decomposes, the soil loses its soddy condition, and drifting develops as soon as the required conditions arise. In sandy soils this may occur in one or two years after breaking.

Cultivation of the soil expedites the destruction of the organic matter in newly-broken land and thereby contributes materially in promoting a soil condition susceptible to drifting. This is true, also, of summerfallow land. The primary purpose of fallowing is the storage of moisture, in the accomplishment of which the soil must be cultivated at intervals to eradicate weeds. Thus, while cultivation is essential for weed control, it may promote drifting if not properly done. The subject of weed eradication in relation to soil drifting is described on page 33 of this bulletin.

The repeated action of frost must be regarded, also, as a contributing cause of soil drifting. In countries with high rainfall it is necessary to plough the land in the autumn in order to utilize the action of frost in improving the otherwise poor tilth of the soil. Such action is actually a detriment on dry farming, or on semi-arid soils, which naturally assume a satisfactory tilth. Frost action is probably responsible for much serious soil drifting, especially in southern Alberta. Here, periods of frost are frequently alternated by the so-called "chinooks", strong winds of relatively high temperature and of decidely low relative humidity. These winds evaporate any moisture which may be present in the surface soil, and if proper precautions are not taken, soil drifting may result. While the land remains covered with snow there is, of course, no danger from drifting.

Access to this farm by vehicular traffic has been completely cut off and its abandonment forced by surrounding drifts of soil three to four feet deep.

When a pulverized soil is wetted and dried, fine particles tend to bind the whole soil mass to form a compact crust or clods that are resistant to the force of wind. Repeated wetting and drying tends to break down the clods to a granulated condition in the manner somewhat similar to that of alternate freezing and thawing. The damage caused by frequent wetting and drying is of minor importance, however, except on some highly calcareous clay soils.

The soil that has been blown about by the wind contains little fine material, or dust, necessary to bind the larger grains together when it is wetted. Therefore, once a field has started to drift, rains do but little good, for if the wind continues to blow, drifting is resumed as soon as the surface is barely dry. Further drifting may be prevented by tillage that would bury this loose material and bring clods from below.

DAMAGE CAUSED BY SOIL DRIFTING

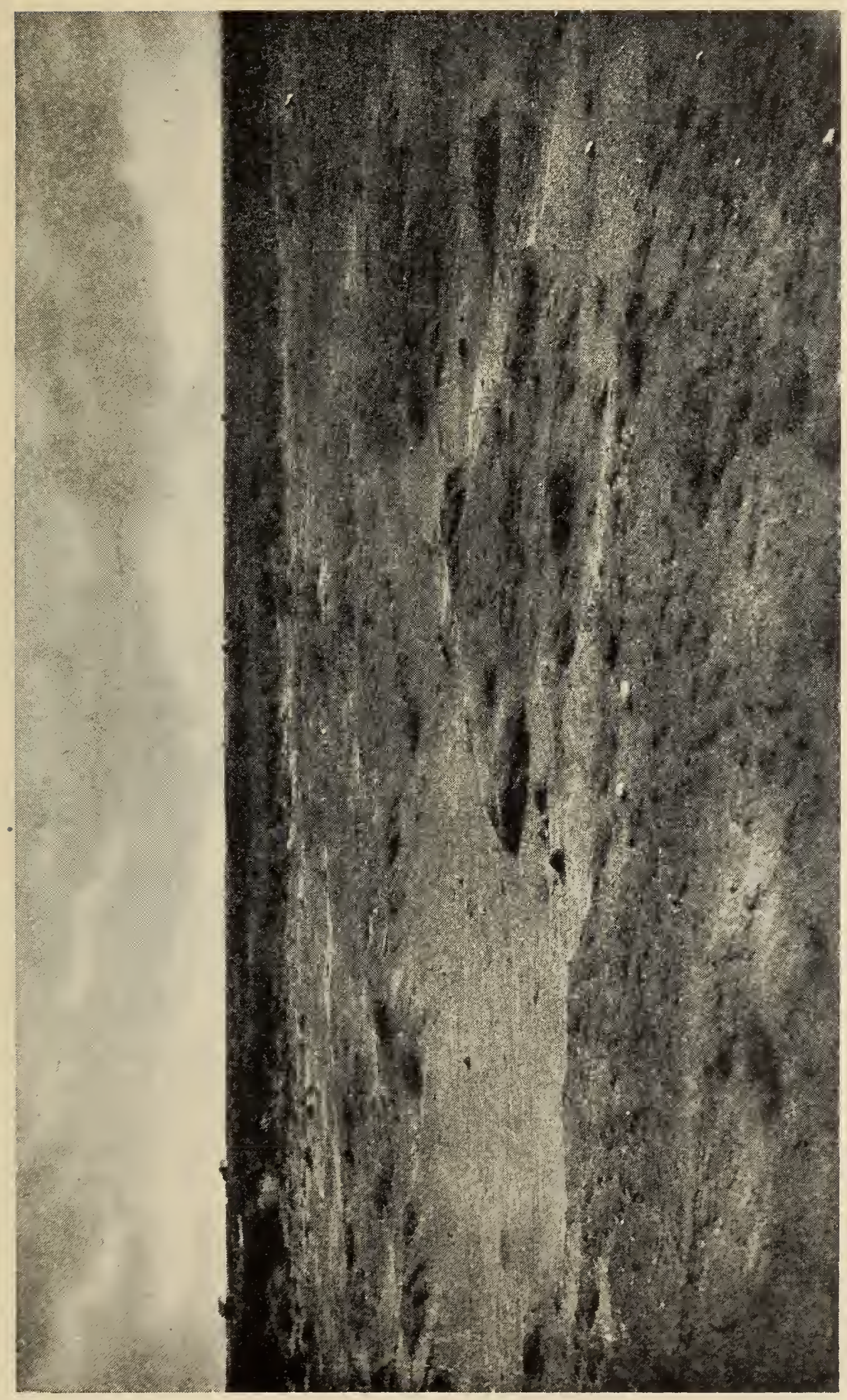
Serious financial loss has been caused by soil drifting over extensive areas throughout the Prairie Provinces. In many instances, farmers have lost their entire crop as a result of direct damage from soil drifting and have had the fertility of their land enormously reduced.

The action of wind on bare, dry soil is much the same as that of a fanning mill on grain. In the case of the soil, the fine material, such as silt, clay, and much organic matter, is continually sorted out from the coarser sands and blown hundreds of miles away. The best portion is thus removed and lagging sand is left behind. In order to find out to what extent soils of the Prairie Provinces have been damaged by this type of injury, extensive investigations have been undertaken on the physical and chemical composition of virgin soils and of nearby soils that had been cultivated for periods ranging from 25 to 50 years.

Analyses show that many cultivated soils are now sandier down to plough depth than they were in a virgin state. The greatest change has taken place on the originally sandy soils which once produced good crops but have since been changed to virtual sand dunes. Good sandy loams have suffered less, on an average about 10 per cent of the original amount of silt and clay having been lost and the sand content increased proportionately. Loam soils show only a slight change and at the same rate it will probably take centuries before any appreciable deterioration to a sandy condition will be in evidence. Clay soils on the other hand show little or none of this type of injury.

The other type of injury is the removal of large quantities of the three essential plant food elements, phosphorus, potassium and nitrogen. Studies show, however, that the subsoils in the Prairie Provinces are generally just as rich in phosphorus and potassium as the surface soil, hence any removal of top soil will not limit appreciably the supply of these elements. Nitrogen is more or less concentrated near the surface. On black soils, a definite nitrogen shortage on eroded soils has been commonly evidenced by spindly growth and distinct yellowish colour of the growing crops. In the dry region of the Prairies, the brown soil zone, there has been no indication that crops were suffering from the general lack of nitrogen. The nitrogen fixing bacteria are apparently abundant and active enough in this region to replace the nitrogen removed by crops and erosion by amounts fixed from the atmosphere. It is the insufficiency of moisture rather than the lack of fertility that has been the chief limiting factor of crop yield in this region.

In other regions of the Prairie Provinces, where two or more inches of top soil have been lost, crop yields have been much lower for many years afterwards. In some cases, the injury appears to be almost permanent.



An extremely severe case of drifting in light soil. Surface and subsurface soils have been eroded to a depth of one to two feet. Checking further erosion and the reclamation of such soils present very difficult problems.

The damage to growing crops by drifting soil is always very evident. Sometimes the germinating seed may be blown away with the soil and the same thing may happen to the growing crop before the plants are large enough to furnish the necessary protection against drifting. Plants that are large enough to protect the soil upon which they are growing may be injured and sometimes completely destroyed by soil, drifting from adjoining unprotected land. In such cases the moving particles of soil cause physical injury to the young plants which are desiccated by the dry winds, or the plants may be buried or smothered by a deep layer of drifted soil.

Drifting soils are also the cause of many other serious problems. The cost of maintaining railway rights of way is greatly increased. Highways are often drifted over and even made entirely impassable. Drifts collected along adjoining roadsides and fence lines furnish an excellent place for weeds to grow and produce seed. Fences that have become clogged with weeds form a check to the wind and may become completely covered with drifted soil. The same condition is experienced with shelterbelts and field windbreaks which are often seriously damaged.

Insect eggs and sometimes the insects themselves are frequently widely distributed with drifting soil, causing more extensive crop losses than would normally be expected. This is particularly true in the case of the pale western cutworm (*Agratis Orthopania* Morr.) where egg-laying is restricted to fields that are especially attractive to the adult females. Drift soil from the roadsides has been used sometimes for gardens and lawns, but often contains so many cutworm eggs that nothing is able to grow until the cutworms have matured. Crops and shelterbelts weakened by soil drifting are more susceptible to injury from many insect pests which cause little damage to strong and healthy plants.

Soil drifting is one of the major causes of the widespread distribution of weeds. Most weed seeds are readily transported by the wind; consequently, fields that are free from weeds often become heavily infested by weed seeds which drift in with the soil from other areas.

One of the most serious aspects of soil drifting is the drifting of soil around and into farm houses. The photographs on pages 7, 33, 44 and 46 show extreme cases but by no means the only ones where drifted soil has covered fences and encroached on windbreaks and farmsteads. Living conditions under such circumstances are extremely disagreeable and often become almost unbearable.

If drifting did not cause any damage whatever to fields or crops and the only injury was to farm homes and their surroundings, its influence on the morale of the rural population, especially the housewives, makes this problem of tremendous importance. It is impossible to keep the dirt out of the home during dust storms. Grit and grime must be endured in food, in beds, in furniture and on the floors until the wind subsides and then it is necessary to clean thick layers of loose soil from everything, only to have the experience repeated with the next wind storm.

The farmstead is not the only home inconvenienced by drifting soils, although the actual injury there has been the most serious. Villages, towns, and even cities have found the dust blowing from adjacent farms a serious nuisance and localities far to the east have reported dust from the prairies settling out of the air. This has been so bad in some prairie towns that traffic on the streets has had to be abandoned during a wind storm. Driving under such conditions has caused accidents on town and country roads. Even in cities it has been necessary to use lights during the day, as is sometimes required in a dense fog.

CONTROL MEASURES

Soil Drifting Control in Different Regions

No standard system of soil drifting control can be recommended for the Prairie Provinces, since measures that are to be adopted must depend on the soil and climatic conditions found in different regions. As conditions vary widely in the Prairie Provinces measures fitted to different local areas are numerous. A careful study of the various control measures described in this bulletin should be made so as to decide from information available what methods would be most suited for any particular set of conditions. Usually not one but several measures must be employed simultaneously, or in sequence, in order that soil drifting may be controlled effectively.

The following measures, where applicable have been found to be quite effective: (1) strip farming, (2) trash covers, (3) cultural methods to create a cloddy or ridge soil surface, (4) seeding down permanently to grass, (5) grass in rotation, (6) field shelterbelts, and (7) cover crops.

The relative effectiveness of strip farming for soil drifting control is approximately the same in any region having the same soil texture, but the extent to which this measure is adopted varies very greatly for many reasons. Strip farming is most widely used in the open prairie sections of southern Alberta and southwestern Saskatchewan, mainly because drifting in these areas is most frequent and acute and farmers are forced to adopt measures that give the soil the greatest possible protection at all times. Opposition on the part of some farmers in the wooded and park areas to adoption of strip farming, or its equivalent, is due principally to the less frequent occurrence of severe soil drifting. In these areas a much wider range of measures is used, such as trash covers, the growing of grasses in conjunction with livestock production, natural windbreaks, and suitable cultural and cropping methods.

A ploughless fallow whereby all crop residues are left at the surface of the ground to give protection against wind and water erosion is adaptable to almost every region and is one of the most promising soil conservation developments in the Prairie Provinces. This measure can and often must be employed in combination with other measures. The value of a trash cover for soil drifting control is limited, however, by the amount of stubble and straw available. In the open prairie region, particularly the brown soil zone, good crop growth is by no means assured and years may occur when insufficient amounts of crop residue may be available for an adequate trash cover. The use of the trash cover, particularly in areas most frequently devastated by drought, should therefore be made in combination with other measures, such as strip farming and the maintenance of a cloddy or ridged soil surface.

Moisture conditions are generally favourable in the wooded and park areas and sufficient trash cover can be maintained nearly every year. The prevention of soil drifting in these areas may also be attained by suitable cropping systems that include the growing of grasses. Apart from supplying fibrous material that binds the soil, grasses increase the size and tenacity of granules and clods comparable with those found under virgin conditions. The introduction of grasses into crop rotations is inadequate and uneconomical in dry regions. Returning badly drifted sandy lands permanently to grass is effective and advisable, but involves many problems connected with agricultural readjustment and resettlement.

Field shelterbelts have been found particularly useful in the park and wooded areas, but in the dry open prairie region great difficulties have been experienced in establishing and maintaining tree growth on a scale sufficient to give the soil the necessary protection. Many splendid belts in this region have

been ruined by a combination of drought, insect damage, and soil drifting. Tumbling weeds, generally abundant in dry regions, are particularly injurious in that they catch in the belts and favour the collection of drift soil.

Cover crops are likewise adaptable only to the more humid sections of the Prairie Provinces. Even in these sections cover crops may be destroyed by grasshoppers, or if sown too early may deplete much of the available soil moisture and defeat the original purpose of the summerfallow. Cover crops are found particularly effective in preventing soil drifting and at the same time supply valuable posture in the foothill region of southern and central Alberta.

Treatment of Different Soil Types

Many failures to control soil drifting have been caused by attempting to adopt measures unsuitable to the type of soil. Since the structure and mechanical composition of soils influence their tendency to drift, methods of handling different soils must be modified to meet the conditions of each soil type. The main factors influencing soil structure, and hence their tendency to drift, are the amount of lime, the amount and composition of the organic matter, and texture. Soil texture is perhaps the most important factor.

Measurements of the relative amounts of soil blown across drifting fields and different widths of strips have shown that the nature of drifting varies widely depending on soil texture. The intensity of drifting at the leeward edge of a field or strip is zero, but increases rapidly on clay and sandy soils and very gradually on loam, clay loam, and silt loam soils. On clay and some sandy soils the distance required for drifting to reach the maximum intensity is generally from 20 to 60 rods, depending on other factors. On soils collectively known as loams, however, the maximum intensity of soil drifting is seldom reached within a distance of 100 rods. At a distance of 20 rods to leeward the intensity of drifting on clay and fine sandy soils is from 50 to 100 per cent of the maximum found near the leeward side of a field of 160 rods in width, but on loam soils it is generally about 25 per cent at the same distance to leeward. This indicates plainly that strip farming is substantially more effective on loams than on clay and sandy soils. It does not indicate that strip farming is ineffective on the latter soils but emphasizes the fact that the width of strips must be considerably narrower to be equally effective. On some highly susceptible sandy soils, strips of fallow may have to be so narrow as to be impractical in many ways. A complete vegetative cover under these conditions appears to be the only solution.

The relatively rapid increase of intensity of drifting near the windward edge of fields on clay soils appears to be due mainly to the presence of a relatively thick loose layer of fine granules that are highly susceptible to erosion by wind. This is especially true on highly calcareous clays such as Regina heavy clay and Sceptre clay and heavy clay. Loam soils are generally covered with a thin surface crust and have relatively few loose granules on the surface. There is therefore a tendency for complete removal of these fractions from the windward side and their gradual concentration towards the leeward, and it is the degree of removal and accumulation of these fractions that is directly associated with the intensity of soil drifting. Very sandy soils, generally of single grain structure, react to drifting much like calcareous clay soils. Those containing a fair proportion of silt and clay have a tendency to form clods and surface crust but the clods and crust are readily disintegrated to erosive grains by the abrasive action of moving soil.

Knolls, sand pockets, and high-lime areas start to drift more readily than the rest of the field. Once drifting has started, however, it spreads fanwise to leeward and the abrasive action of the moving soil causes drifting on the remain-

ing parts of the field. This situation is encountered generally on loam soils. Strip farming is particularly useful under such conditions for it limits the spread of drifting to a particular strip or portion of the strip and gives the farmer some opportunity of checking soil drifting in its incipient stage. Clay soils and some sandy soils seldom have a surface crust but the whole surface is often composed of a bed of highly erosive grains. Drifting under such conditions is more or less spontaneous over the entire field or strip, unless the whole area is protected with a good trash cover or ridges. Ridging helps for a time, but the furrows may soon fill up and the protection they offer is lost. This is especially true on sandy soils.

In view of the fact that soil texture plays a prominent part in determining the relative susceptibility of a soil to drifting, it will be convenient to deal with methods of soil drifting control on that basis. In this connection, the soils may be divided into three broad textural classes: sandy soils, loam soils, and clays.

Sandy Soils.—Sandy soils vary greatly in the amount of silt and clay they contain, hence the relative resistance of clods to abrasive action and consequently the maximum width of fallow strips, where strip farming can be recommended, vary considerably. On fine textured sandy loam soils in areas of moderate or favourable rainfall, strips should not exceed 10 rods in width, and should preferably be narrower. A ploughless fallow should be fallowed with special attention to keeping all the trash possible on the surface for protection. If a good trash cover has not been maintained and if moisture and insect conditions permit, it is usually advisable to seed a cover crop late in July. In dry areas it is generally unwise to fallow sandy soils, even in narrow strips. In these areas farmers "stubble in" their sandy soils from year to year, taking a chance on securing a crop in preference to accepting the hazard of losing both crop and soil if drifting occurs. Where returns are particularly poor, due to drought, weeds and other causes, it is best to leave very sandy soils permanently in grass or a grass legume mixture for hay or pasture.

In the more humid sections of the Prairie Provinces sandy soils are less of a problem and soil drifting may be prevented by trash covers and suitable crop rotations which include grasses as the main soil improvement crop. Even in these areas very sandy lands have drifted severely and the only reasonable solution seems to be to maintain such lands permanently in grass.

Sandy soils are likely to drift despite almost any precaution that might be undertaken. They are especially difficult to manage after drifting starts because clods cannot be formed and ridges are readily levelled down by drifting soil. Focal points should be watched and deep furrows ploughed to prevent the drifting area from spreading, and if straw or manure is available they may be applied to advantage. Badly drifting knolls should be seeded down permanently to grass.

Packing moist soil immediately after working or seeding is particularly useful on sandy soils. If at all possible, sandy soils should be worked only when moist, for they pulverize very readily when dry.

Loam Soils.—These include loams, silt loams, clay loams, and silty clay loams. Strip farming in its various forms combined with suitable cultural practices have been found particularly useful on these soils. Since the prevention of drifting can be achieved either by creating a cloddy surface or maintaining a heavy trash cover or a combination of both, a much wider range of cultural practices than is possible on clay or sandy soils may be employed with success. In fact, there are so many effective methods that there is little reason for permitting such soils to drift.

Clay Soils.—Clay soils readily disintegrate to a loose granulated condition, particularly as a result of freezing and thawing during the winter months. Drifting is therefore more severe following a winter with little snow cover. The severity of drifting varies depending on degree of granulation. Regina heavy clay disintegrates most readily into small granules, followed in order by Sceptre heavy clay, Drumheller clay, and Red River clay.

Due to great uniformity of the granulated surface, soil drifting usually starts all over the field at the same time and once started it is quite severe, even in narrow strips. Strip farming is therefore less effective on clay than on loam soils, although it reduces the severity of drifting somewhat if the strips do not exceed 20 rods in width. Under severe conditions they should not be over 10 rods in width but such widths are not very practicable.

Due to more favourable moisture conditions on clay than on other soils, the maintenance of a heavy trash cover is particularly beneficial and feasible. If the trash cover is thought insufficient to hold the soil, deep furrows should be made at narrow intervals across the field to trap the moving soil. Cultivator ridges on soil such as Regina heavy clay are too small to be effective for very long, but they have a definite advantage on soils such as the Red River clay. Packing with a surface packer or float when the soil is moist has a temporary beneficial effect. Deep single disking to turn up moist soil to the surface where it will bake and form clods will prevent drifting, probably until the crop has made sufficient growth to give complete protection to the surface. The main objective on clay soils should be to maintain as heavy a trash cover as possible commensurate with effective control of weeds.

Strip Farming

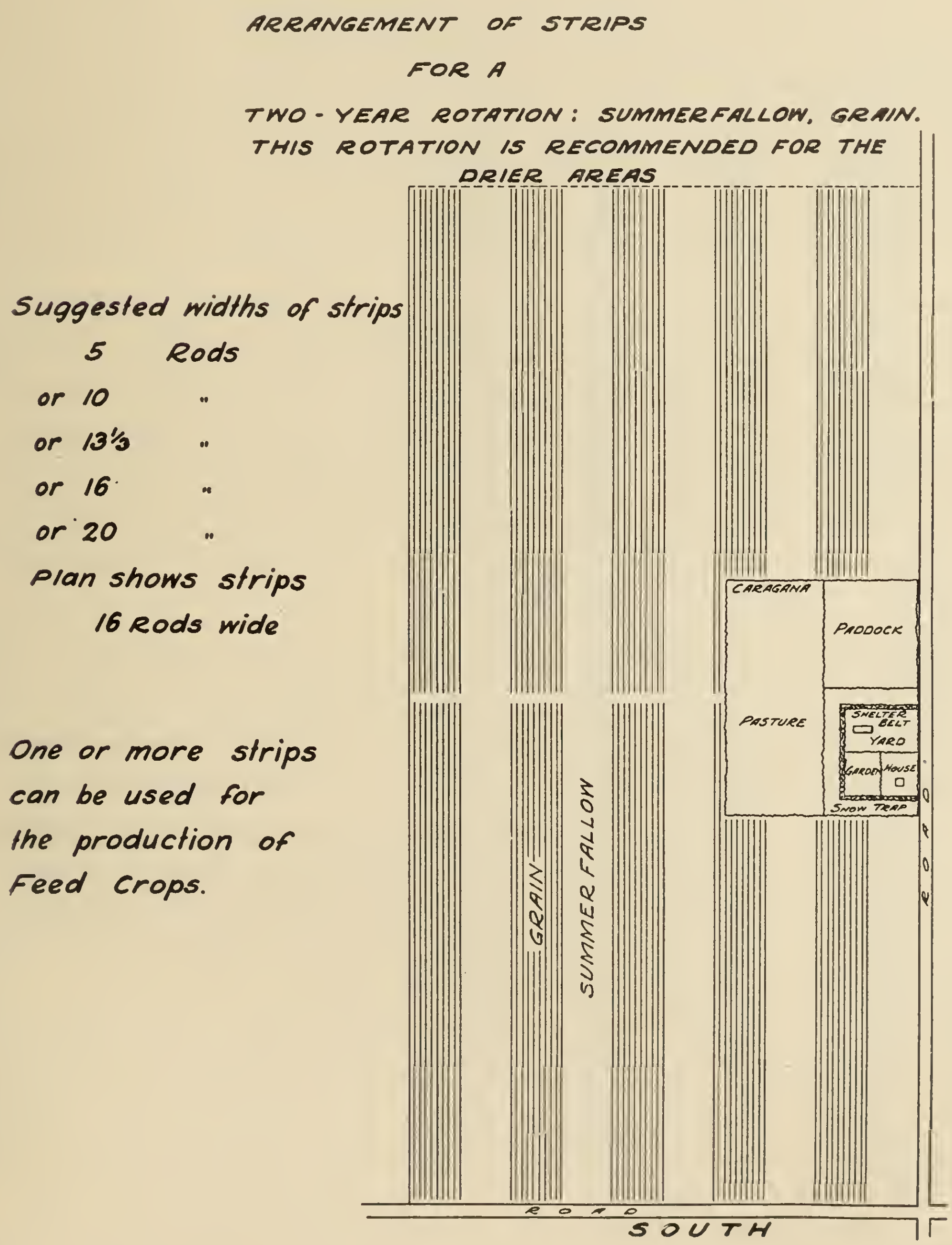
Origin of Strip Farming.—Strip farming is a method of soil drifting control which does not appreciably alter cropping practices. When the sod was first worked out of the soil and fallows began to drift, many people advocated the abandonment of the summerfallowing practice. Most farmers and investigators realized, however, the necessity of summerfallowing, but many farmers became so discouraged in trying to keep the soil on their fallows that they either sold their farms or abandoned their land. Some farmers near Monarch, in southern Alberta, noticed that the last place to drift was on the west part of their fields and that the prevailing winds were generally from a westerly direction. They noticed also that frequently the west ten or twenty rods of the field did not drift at all if drifting conditions were not too severe. These observations soon led to a division of the fields into alternate strips of fallow and grain, a practice which has been so helpful that it has now been widely adopted, especially in southern Alberta where its value was first recognized.

Farmers in this region have been strip farming for over 25 years. They have been able by this means, along with proper cultural practices, to practically prevent drifting on their farms, although unstripped fields in the same vicinity have drifted nearly every year. During recent years, strip farming has been tried in various parts of the prairies with satisfactory results.

Precautions Necessary.—Notwithstanding the demonstrated benefits of strip farming, numerous farmers have stripped their fields and yet soil from the summerfallow has been blown over into adjoining stubble to form a series of ridges and depressions. This experience has undoubtedly arisen from a mistaken idea that stripping alone would prevent summerfallow from drifting regardless of the condition of the soil. It is important, however, to ensure that the best cultural methods be adopted for summerfallow strips, in order to secure as much trash cover as possible, or to maintain the soil in a lumpy condition, as

outlined under "Treatment of summerfallow to control drifting" on page 19. There are other precautions to be discussed later, which must be taken to prevent undue losses from insects. Farmers who have had long experience with strip farming have learned, however, that stripping is only an aid, although a very

STRIP FARMING PLAN
FOR A
HALF SECTION FARM



useful aid, in holding their soil. One farmer expressed the situation very well in this way: "By careful cultivating my summerfallow strips I have had no drifting for eight years, but if my summerfallow were in a very large block I know of no other way that I could conduct an effective fallow and keep my soil."

Arrangement of Strips.—Stripping is usually started on a field in the year when it is to be followed by dividing it into strips of the desired width, seeding alternate strips to spring grain and leaving the other strips to be fallowed. This arrangement of the strips is followed where the practice is to summerfallow every other year. If the land is to be fallowed only once in three years, two strips should be seeded to spring grain and the third one fallowed. Suggested arrangements in diagrammatic form are shown on pages 15 and 17.

Another method of starting strip farming is to seed the stubble land in strips in the fall to fall rye. The following year the fall rye may be cut for grain or hay while the intervening strips are summerfallowed. If it is not desired to seed wheat on all the summerfallow, strips of fall rye might be seeded in the fall of the year the land is fallowed, the crop being cut for grain or hay, or strips might be seeded in the spring to green feed, intervening strips being seeded to wheat. In both cases the strips in fall rye or green feed should be ploughed or cultivated immediately after the crop is removed so as to provide a partial summerfallow. These latter methods of commencing strip farming are not considered as generally satisfactory as the method first outlined, but are suggested as alternatives in order to meet various local conditions. Where wheat stem sawflies are a problem special methods of installing strips are required as discussed later in the section dealing with insect control.

Direction of Strips.—Strips are usually laid down in a north and south direction, which is approximately at right angles to the most frequent winds. Some have thought that strips are of value only where drifting winds come from one direction, that is at right angles to the strips, but this is not substantiated by experience, as they have been found to furnish some protection from winds striking them at almost any angle. North-south strips, for example, protect the soil from winds coming from any direction except due north or due south. Even when a wind comes that is parallel to the strips, it is not likely to be as injurious as on unstripped fields because the soil on the strips has not been broken down to a drifting condition by other winds.

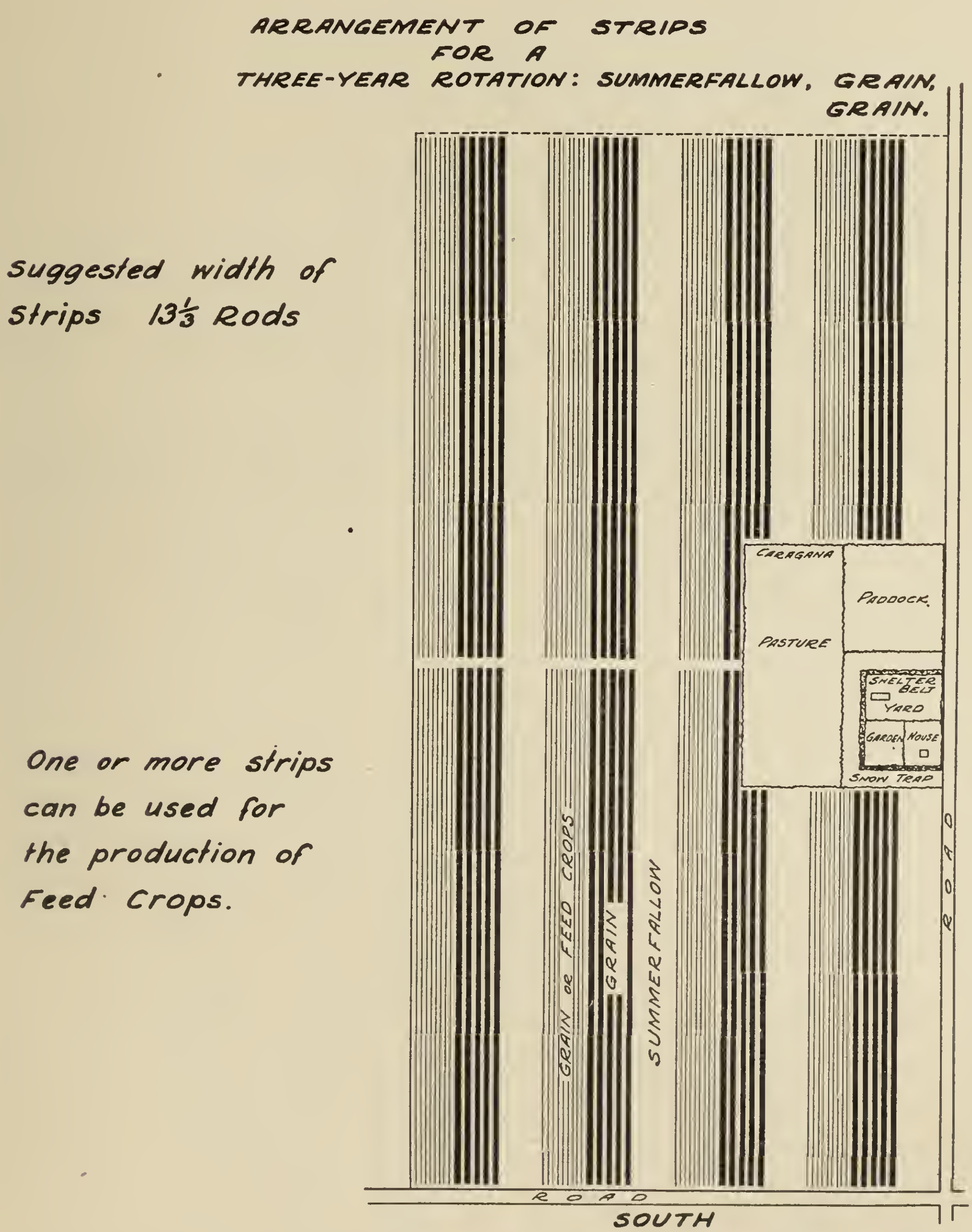
Width of Strips.—The most satisfactory width of strip varies with the seriousness of drifting conditions, but is usually from 10 to 20 rods. On some light soils strips as narrow as 5 rods are used. Convenient widths of strips for a quarter-section of land would be 10 strips of 16 rods each, 16 strips of 10 rods each or 12 strips of 13⅓ rods each.

Inconveniences of Strip Farming.—Strip farming has some disadvantages but if soil drifting is a problem the inconveniences are far outweighed by the benefits. Like most new practices, many of the objections raised against stripping by those who have not tried it, are found to be of little or no consequence. They are seldom mentioned by those who have adopted the practice. Some of the difficulties, however, are real and must be met.

The tendency of soil to ridge at the windward edge of the stubble strips is one of the most objectionable features. It may be overcome by proper cultural methods. When it is encountered, however, the practice may be followed of breaking down the stubble with a disk on the windward side of the stubble strip for a distance of one or two rods. This permits any drifting soil from the summerfallow strip to distribute itself over this disked portion of the stubble and so no abrupt ridge is formed. Under extreme conditions the above method may necessitate gradually moving the strips of summerfallow and crop to the leeward side across the field. This is accomplished by seeding the area of disked stubble on the windward side of the strip in addition to the land previously summerfallowed. The seeded strips are thus increased in width by one or two rods and those to be followed are decreased by this amount. In the following

fall the procedure of disking a strip of stubble on the windward edge is repeated. This practice automatically moves the strip a rod or two toward the leeward side of the field and has a tendency to spread any drifting soil uniformly over the field. It should be stated that very few farmers have followed this practice as almost invariably they have been able to control drifting on their strips sufficiently to prevent any serious piling of the soil.

STRIP FARMING PLAN
FOR A
HALF SECTION FARM



Another difficulty encountered is the tendency of such weeds as Russian thistle to grow along the edges of grain strips. This can be overcome by carefully cultivating right up to the edge of the grain or by seeding grain two or three feet over into the stubble when the summerfallow strips are seeded in the spring. As the stubble strips are cultivated during the summer for fallowing,

Strip farming in southern Alberta.—As a measure of soil drifting control, strip farming has been widely adopted throughout entire districts as a community action. For most effective control strip farming should be combined with surface cultivation of the land rather than ploughing.

the cultivator can be extended about a foot into the extra seeding of growing grain at each cultivation, thus preventing the growth of weeds along the edge of the grain.

Farmers have occasionally found some difficulties in strip farming arising from grasshopper and sawfly infestation. Special methods, as discussed on page 35 of this bulletin, have been developed for handling insects where stripping is practised.

This photograph shows strip farming in the Monarch district in southern Alberta where this method of controlling soil drifting has been extensively adopted. The farmers in this district not only practice strip farming but follow the best cultural practices to prevent drifting, including ploughless cultivation to maintain stubble and trash on the surface.

A few other inconveniences are usually thought to be important by those who have not tried stripping or are just starting but are seldom mentioned by those who have followed the practice for a few years, which indicates that they appear to be of more importance than is proved by experience. Among these inconveniences are longer hauls or "sets" in threshing, time lost in moving equipment from one strip to another, roads required along the headland to work strips, impossibility of cross cultivation and the inability to pasture fallowed fields in the summer. Where extremely large outfits are used, the farmers seldom like to practise strip farming but with ordinary power equipment there is little complaint. Surveys made by the Dominion Experimental Station at Lethbridge, Alta., indicate that the cost of operation is not appreciably greater on stripped than on unstripped land.

Treatment of the Summerfallow to Control Drifting

Two important methods of summerfallowing land have developed on the prairie, one in which the land is ploughed and one in which the land is not ploughed, but is cultivated with surface tillage implements only. These methods are usually called ploughed summerfallows and ploughless summerfallows.

Ploughless Summerfallow.—The basic principle of the ploughless fallow is to keep down weed growth without burying the stubble and other plant residue so that this material may be left on the surface to form what is termed a "trash cover" as a protection for the soil against erosion. This is but copying nature's method of reducing damage to the soil by keeping it covered.

The effectiveness of ploughless tillage for erosion control depends on the amount of material that is maintained on or in the surface soil. If considerable

trash is left, drifting is controlled but if little or no covering is maintained the soil is more likely to drift than it is if ploughed, as the subsurface tillage of ploughless fallowing does not leave a lumpy surface.

The surface soil has been completely blown away from this area. No vegetation has appeared on this wind swept spot since 1931. The productivity of the land undoubtedly has been very seriously impaired.

In areas where drifting is serious almost every year, such as the Chinook belt of southern Alberta, farmers and investigators have developed special methods of cultivation to permit satisfactory tillage for weed control without destroying or burying the plant material. Cultivators have been devised with long blades and high shanks that will go through heavy stubble and tumble weeds without clogging. These blade cultivators are described more fully in the section of this publication dealing with Machinery for Soil Drifting Control. Also, the action of the one-way disk and the common disk have been studied and their use limited to fields where there is a heavy stubble or only a light, shallow cultivation is given. Seldom is it safe to use the one-way for more than the first cultivation unless there is a very heavy cover. Subsequent strokes are given with a rod weeder or a blade cultivator. The ordinary duckfoot cultivator can be used for ploughless tillage where the stubble is not too high and there are no tumble weeds.

There seems to be no decrease in crop yields from ploughless tillage as compared with ploughing on most soils if fields are kept clean of weeds and drifting is controlled. Ploughless farming has been practised in Western Canada since 1915 and numerous and long period tests have been made on experimental stations. Seldom has there been any indication of decreases in yields where fields have not been ploughed for many years but frequently the production is slightly higher.

One thing that must always be remembered regarding ploughless fallowing is that it is effective for erosion control only if sufficient trash is left on the surface to protect the soil. The skill of a farmer in this practice can be measured by the amount of cover he can leave without permitting weeds to grow that use up moisture from the fallowed soil.

If an unploughed fallow has not a sufficient trash cover it should not be subjected to the drifting hazards of the fall, winter and spring period without additional protection. Such fields either should be seeded to a cover crop, listed, or converted into a ploughless fallow by ploughing in late summer or early fall. Ploughing for this purpose should be deep enough to turn the dust mulch under and leave a lumpy surface.

Ploughed Summerfallow.—Ploughing of summerfallows still is practised in parts of the prairies, principally in the localities of higher precipitation where it is more difficult to kill weeds without turning them under. As ploughed lands have no trash cover protection they must depend on the roughness of their surface to resist erosion. Therefore, it is extremely important to maintain a lumpy surface structure on such fields and failing this it becomes necessary to ridge with some kind of a lister as discussed later.

The basic principle for maintaining a lumpy surface is to plough as late in the season as is feasible and to cultivate as little as possible after ploughing. It has been found that this can be accomplished most satisfactorily by conducting a ploughless fallow during the early part of the season and ploughing as the last operation. This ploughing can be done in late July or early August in many localities without sufficient weed growth developing before killing frosts occur to require additional cultivation. Where perennial weeds are present that require late cultivation the ploughing can be delayed until the fall.

Ploughed fallows usually have proved to be safe on medium textured soils where the ploughing is made the last operation. The clods turned up by the plough on sandy or clay soils decompose so rapidly that it is not safe to depend on even late ploughing for protection against drifting. Fall listing is the most safe practice for bare fallows on such soils. The one-way disk perhaps is the best implement to use for keeping fields clean before delayed ploughing as this implement kills weeds more readily than most other cultivating tools when no attempt is made to maintain a trash cover.

Spring Treatment of Summerfallow.—The summerfallow should be watched during the winter months, if the land is bare of snow, and also in the early spring. If signs of soil drifting are observed, preventive measures should be employed immediately. These are described in detail under the heading of "Emergency Measures." A fairly deep cultivation is often required in the early spring to prevent bare summerfallows from drifting.

It is almost invariably a good practice to cultivate the soil immediately before seeding to destroy weeds. If after this treatment there is danger of soil drifting it may be advisable to use the duck-foot cultivator, set deeply enough to bring up lumpy soil to the surface. Where the surface soil is dry and loose it may be necessary to use the cultivator provided with narrow teeth or the spring-tooth harrow in order to penetrate to moist soil and to bring up clods to the surface. As with summerfallowing it is a good practice to use as little tillage as possible by which weeds will be destroyed and a lumpy condition of the soil created. Excessive pulverization of the soil is most likely to occur when tillage is done under very dry conditions. Ploughing with a mouldboard plough immediately before seeding is one of the most effective ways to prevent soil from blowing until the crop is high enough to afford protection. Where the soil appears to be in a drifting condition immediately after seeding, ridging with ordinary duckfeet on a cultivator has proved effective.

From the Dominion Experimental Farm at Brandon, Manitoba, comes a recommendation to cultivate the summerfallow in the early spring, using a cultivator provided with narrow points, and not to exceed a depth of two or

three inches. This cultivation is done while the land is still moist from the melted snow. Seeding is done immediately in order to utilize the soil moisture in promoting a more rapid germination, thereby hastening the maturity of the crop and reducing the liability of crop injury from rust.

When provided with ridging shovels placed 3 to 4 feet apart, the cultivator is useful for emergency soil drifting control measures. The surface of a field can be quickly transformed into a series of ridges and hollows with this implement.

Cover Crops

A very effective method of controlling soil drifting which is used on summer-fallow in some localities where a fair rainfall is received, is to protect the field with a cover crop. This consists of a late summer seeding of spring grain. If the crop makes a satisfactory growth the soil is effectively protected. Where the fall growth is very heavy some excellent fall pasture is also secured. A cover crop, however, should not be pastured to the extent of destroying its protective value. In and near the foothills of Alberta, where moisture is fairly abundant, the use of cover crops is quite general and farmers maintain that the actual reduction in yields of subsequent grain crops as a result of using cover crop, is very small. Due to limited moisture conditions in the drier sections of the prairie, however, in which drifting is even more acute, the results with cover crops are not as a whole so satisfactory. Strip farming combined with proper cultural methods is the safer protective measure in such areas.

The chief objection usually made to the use of cover crops is the loss of moisture by transpiration. Experiments with cereals seeded in spring indicate that the available soil moisture decreases relatively slowly at the beginning of the growth period of the cereal plant but decreases more rapidly as the transpiring leaf area is increased. A very rapid decrease in the soil moisture begins about the time the crop has attained the height of about five to six inches. Some moisture used up by the growth of a cover crop may, however, on fairly level land and under substantial winter precipitation be regained by the additional amounts of snow trapped. The results of determinations of soil moisture indi-

cated no appreciable loss when a cover crop was sown at about the beginning of August, but very appreciable reduction in moisture took place when a cover crop was sown earlier.

The yields obtained on a cover-cropped summerfallow are often about equal to those sown on a bare summerfallow, although with heavy growth and in dry regions, very serious decrease following such treatment may take place. The five-year average yield of wheat on a heavy clay soil at Regina off summerfallow on which a cover crop was sown on about August 5 of the previous year was 16·6 bushels per acre as compared with 12·4 bushels per acre off a bare summerfallow which in some years drifted badly. The increase in the yield on a cover-cropped summerfallow in this case is partly attributable to the fact that some drift soil blew off the bare summerfallow plots and was trapped in a shallow layer over the cover-cropped plots. Yields from treatments which were not so affected show smaller differences in favour of a cover crop. The reduction in yields on a bare summerfallow, on the other hand, was a result of crop injury by drifting soil and a loss in productiveness through the removal of surface soil, which was prevented by the use of the cover crop.

In addition to the possible loss of soil moisture there are several other objections to the use of cover crops. First, there is an added expense in seed and seeding. Then drought and grasshoppers may sometimes destroy a cover crop, leaving the soil unprotected and susceptible to drifting. During years of grasshopper abundance the cover crops are quite difficult to protect by spreading bait. If pale western cutworm damage is to be expected, seeding must be done prior to August 1 and the land left undisturbed until September 15. Furthermore, there may be also a difficulty in controlling certain weeds where cover crops are grown. During dry years it has sometimes been difficult to establish cover crops due to the lack of soil moisture required to germinate the seed. Where these difficulties have been experienced some farmers have adopted strip farming and are maintaining trash cover in addition to the cover crop. Perhaps cover crops should be used as an emergency method to be used when strip farming combined with trash cover does not provide sufficient protection. Spring treatment of summerfallow which has had a cover crop is similar to that used where none was grown.

Rates of Seeding.—The rate of seeding cover crops has been one-half of a bushel of spring wheat per acre or three-quarters of a bushel of oats or barley. These rates have produced very effective cover crops, which have prevented the drifting of summerfallow land even under severe conditions. Slightly different rates may have to be used on different types of soil. When a cover crop is seeded rather later than usual somewhat higher than normal rates are more desirable so as to give the land sufficient protection.

Methods of Seeding.—A common method of seeding is that generally used in the seeding of ordinary grain crops except that the rate is considerably reduced. Another method is to seed with every other drill run closed. This latter method may be used to some extent where drifting is not very severe, but a general objection to it is that with a small amount of growth of the cover crop the more susceptible lands, such as sands and clays, tend to drift to some extent between the rows of grain. If for any special reason this method of seeding is necessary it should be done somewhat earlier in the season and at right angles to the prevailing winds, in order to secure greater protection.

Dates of Seeding.—The optimum date of seeding cover crops cannot be set definitely for such a large area as the prairie where considerable variations in soil and moisture conditions occur. Variable conditions from year to year also influence the time at which it is best to seed a cover crop. Under most conditions the cover crop should be seeded about August 1, but never later than this if a

pale western cutworm outbreak is expected. In the park areas where moisture conditions are favourable and fall pasture is desired cover crops could be seeded somewhat earlier. When grasshoppers are prevalent it is often advisable to delay seeding until later in the season when the majority have ceased feeding. On the other hand, where cutworms are present it is not advisable to seed later than August 1, since later cultural operations tend to favour cutworm activity. The principle involved in selecting the date of seeding of a cover crop is to seed early enough to ensure sufficient growth to protect the soil but not to seed so early that more growth is secured than is needed, and so avoid unnecessary depletion of soil moisture.

A cover crop consisting of spring grain seeded around August 1, at the rate of about ½ bushel per acre is very effective in controlling soil drifting. After being killed by frost the cover crop is still effective in checking drifting during the winter and spring months.

Choice of Cover Crops.—Information at present available does not indicate any appreciable difference in the protection afforded by spring cereals used as cover crops. It is preferable, however, to use the same kind and variety of grain for cover crop planting as will be seeded on the land in the following spring. This precaution will avoid contamination by volunteer plants from seed which did not germinate in the previous fall. Oats as a cover crop may be objectionable if the seed is not entirely free of wild oats. Some farmers prefer to use barley for this purpose, their reason being that under somewhat dry soil conditions it germinates and makes a surface cover quicker than the other cereals. Oats are used exclusively in western Alberta where late July sown cover crops are used extensively for fall and early winter pasture. In this area the fattening of cattle for market on these cover crops has become an important business.

EMERGENCY MEASURES

Although the use of some permanent means to control soil drifting is highly desirable, emergency measures may be required where systematic precautions have not been observed. Emergency measures can be used to advantage where soil drifting is of relatively infrequent occurrence and has not reached serious proportions. In some cases these measures must be applied while soil drifting threatens, or is actually in progress. On these occasions prompt and energetic action is essential. It may be necessary sometimes to supplement a permanent control practice with emergency measures. In principle these emergency

Land worked with a cultivator provided with ridging shovels offers a very effective barrier to the movement of soil. This land must be levelled, of course, before seeding. Levelling can be done with a duck-foot cultivator run parallel with the furrows.

Drifting may occur in the winter if the snow goes off. In such cases the frozen soil can be ridged with a lister made by removing all but every fourth or fifth disk.

measures closely resemble the permanent practices in that they aim to place obstructions in the path of moving soil in order to check drifting before it can assume appreciable proportions.

Drifting may occur in the winter if the snow goes off. In such cases the frozen soil can be ridged with a lister made by removing all but every fourth or fifth disk.

The following emergency measures, where applicable, have been found effective:—

1. Listing summerfallow fields in the fall.
2. Ploughing furrows one rod apart through the field.
3. Ridging by means of the duck-foot cultivator.
4. Application of straw or manure.
5. Disking during winter months.
6. Reploughing deeply.

Summerfallowed fields on which it is feared that soil drifting may take place during the fall or winter may be ridged or listed in the fall. This form of ridging may be done by equipping every fourth or fifth shank of the duck-foot cultivator with a ridging shovel as shown in the photograph of this arrangement on page 22. Equipped in this manner the cultivator is used in the fall to make furrows three to four feet apart across the field at right angles to prevailing winds. To be effective the furrows should be deep enough to throw up two or three inches of new soil to form a lumpy protection at the top of the furrows. The placing of shovels on every fourth shank appears more desirable than to have them closer as a flat ridge is left between the furrows. This ridge resists wind action for a longer period than a narrow V-shaped ridge.

An objection raised to listing is that when the field is levelled in the spring, which is usually done by cultivating with a duck-foot, the furrows are filled with dry soil and if the spring is dry uneven germination may result. Farmers who have listed their fields in this way for several years, however, have had little difficulty with faulty germination.

Listed fields can easily be levelled again for seeding merely by cultivating with a duck-foot cultivator going in the same direction as the listing furrows.

Listing is so effective and so easily done that it seems wise to advise that every field that appears to be in danger of drifting in the field should be listed and wherever drifting gets beyond control by other measures, listing should be done.

Where fields become bare of snow in the winter and start to drift when the soil is frozen, the drifting can be stopped easily by listing with a one-way disk from which all but every fourth disk have been removed. A single disking also will temporarily check drifting on frozen soils but the soil may start to move again after several windy days while fields listed with the one-way seldom have given any more trouble before seeding time.

Ploughing furrows one rod apart through the field has furnished some protection. This has been done most frequently when drifting threatened on seeded fields. Harrowing has kept some seeded fields from drifting when a surface crust had been formed that the harrow could break up into lumps. As an extreme emergency in seeded fields the duck-foot cultivator may be used on focal points such as knolls or ridges where drifting is in progress, or the entire field may be cultivated with narrow spring teeth placed a foot or more apart.

The duck-foot cultivator is employed quite extensively for ridging summerfallow and ploughed stubble land. Some people on light soils condemn the use of this implement for ridging. There is little question that if this implement is used at all for ridging the shovels must go deeply enough into the soil to bring

up lumps from below and to permit the loose top soil to sift down. A narrow toothed cultivator is sometimes more useful for this purpose when the top two or three inches of soil is dry and loose. Deep cultivation of this nature in the fall, winter, or spring has undoubtedly saved many fields.

Covering drifting fields with straw is being practised more extensively than many realize; in fact, in a few localities this practice is quite common. One farmer who spread straw over about seventy-five acres reported that it required three days to do this work with three men and two teams. This method is especially desirable when drifting starts on seeded fields. If the straw is spread on spots as they first start to drift it is often unnecessary to cover the entire field. Straw covering is also one of the effective means of checking winter drifting when the soil is frozen and the lister or cultivator cannot be used. In some areas spreading of manure over the field in the fall, winter or spring is very effective in preventing soil drifting. Throughout large areas of the prairies, however, this cannot be practised as grain growing constitutes the main enterprise of the farm.

Knolls susceptible to drifting are often responsible for starting whole fields to drift. These focal points in the field must be watched carefully and control measures put into effect before extensive damage has been suffered. Spreading manure or straw over these spots is generally effective. The best solution, however, is to return these badly drifting knolls to permanent grass.

TREATMENT OF STUBBLE LAND TO CONTROL DRIFTING

Soil drifting is not often experienced on stubble land that is being prepared for spring grain unless the stubble is burned off and a high wind comes up before the field is cultivated after burning. There have been a number of occasions, however, when burned-over fields have drifted out to the bottom of the plough furrow in a few days where they have been left without cultivation.

Loam soils that have had the stubble burned off are not likely to drift for some time after they have been cultivated, but sandy or flaky clay soils that are so treated may drift badly before the crop makes sufficient growth to furnish the necessary protection. Stubble should not be burned, therefore, on soils that drift readily, but the seed-bed should be prepared by cultivating so as to leave stubble on the surface as a protection.

Shallow spring ploughing has been satisfactory for medium soils and good results have been secured by cultivating and seeding stubble land in one operation with a one-way disk equipped with a seeder attachment where moisture conditions were favourable.

Fall ploughing of stubble is not recommended when the soil is dry, in fact, ploughing under these conditions is not good practice at any time as soil ploughed when dry has a tendency to break down to dust quite readily by the action of the weather. Numerous experiments have also shown that smaller yields may be expected on stubble land ploughed in the fall when dry than on spring ploughing. As a result of very marked reductions in the yields, even on spring ploughed stubble, ploughing has been completely abandoned on some heavy clay soils, the land being surface worked.

Where the soil is moist, fall ploughing is usually satisfactory for loam soils but dangerous for sand and some clay soils. When the surface soil is extremely dry and loose, and yet not drifting, it may be inadvisable to disturb such land unless absolutely necessary for weed control.

MACHINERY FOR SOIL DRIFTING CONTROL

The aim in selecting farm machinery is essentially to secure equipment that will do the desired work in the most efficient manner. Tillage implements are primarily designed for the efficient control of weeds. However, where soil drifting may occur great care should be exercised in the use of these implements as too frequent or too thorough tillage promotes drifting.

Field Cultivator.—The chief merits of the field cultivator are that it produces a minimum of soil pulverization and is fairly effective in the destruction of weeds. Equipped with duck-feet, it may be used for the cultivation of ploughless fallows with a minimum destruction of trash covering. It may also be used on ploughed fallows, both before and after ploughing, and for the spring cultivation of summerfallow land. Equipped with duck-feet or narrow points, the cultivator may be used to loosen the soil prior to rod weeding. The cultivator may be equipped also, with ridging shovels as shown in the photograph on page 22, and be used for ridging as described under "Emergency Methods." Although adaptable to a wide range of conditions the field cultivator may become clogged in heavy stubble or land infested with Russian thistle. By removing the clogged material at intervals, however, and by setting the duck-feet deep enough to go below the root crowns, satisfactory work may be done even under quite adverse conditions.

Blade Cultivators.—Ploughless tillage and the use of the trash cover to protect soils against drifting have stimulated the inventive urge of farmers and investigators to develop implements that would till unploughed ground and kill the weeds without covering stubble and other plant residue. Heavy cultivators with long blades and high shanks that would penetrate hard soil and would not clog in heavy trash have been the most successful implements devised for this purpose.

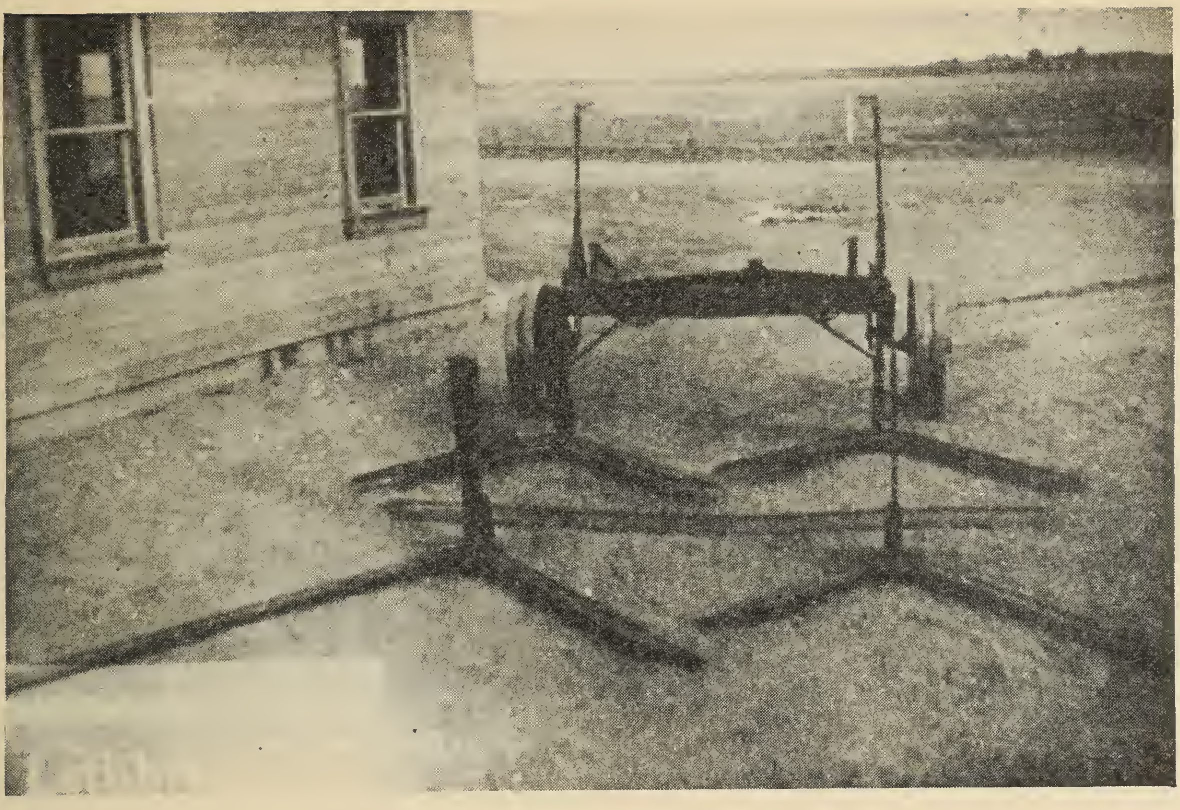
Two kinds of blades, straight and V shaped are in use (see cut). Straight blades operate successfully on medium textured soils that do not tend to pile up ahead of the blade, and where there are no tough rooted perennial weeds. V-shaped blades are preferred on loose soils and for fields containing woody rooted perennials.

The advantage of heavy blade cultivators is that fields can be cultivated with little disturbance of the plant residue cover and when properly constructed will go through a great amount of trash, penetrate hard ground and can be used on quite stony land.

The principal disadvantage of these cultivators is that they may not disturb the soil enough to kill the weeds, especially if the soil is wet or if a rain is received soon after cultivating. Some progress has been made in overcoming this difficulty by using sloping blades that disturb the soil more than does a flat blade. Rods are attached behind some machines to shake the soil away from the weed roots. Driving at higher speeds also is beneficial and it is always desirable to run the blades as shallow as possible.

If blades are used in dry weather, usually little trouble is experienced so these machines are increasing in popularity in the drier areas and are replacing other tillage implements. This is fortunate for it is in the dry localities that drifting is the most troublesome and there is the greatest need for trash cover farming.

One-way Disk.—The one-way disk is of value for soil drifting control if it is used in a way that leaves sufficient trash on the surface to hold the soil. It is effective in destroying weeds, and leaves the soil in a somewhat roughened condition. This implement has been particularly useful for the first operation on heavy combine stubble, on a heavy growth of weeds or on a combination of both in the preparation of ploughless summerfallow. Shallow disking covers



Blade cultivator showing different types of blades. Lower photograph shows the large amount of stubble left on the surface to check soil drifting after the use of the blade cultivator.

Where soil drifting may occur, the duck-foot cultivator performs several very useful functions. It may be used to prepare the soil instead of ploughing. It is very effective in destroying weeds. It does not unduly disturb the surface soil and it leaves stubble and trash at the surface as a protection against drifting.

less trash than does deep disking. The concavity of the disks and the speed of operation also influences the extent to which the trash is covered.

It is usually not advisable to use the one-way disk for the second operation on a ploughness fallow as there is danger that the trash may be covered too thoroughly, leaving insufficient protection. Similarly, it is very inadvisable to use the one-way disk in light, clean, binder stubble as preparation for ploughless fallow. The short stubble may be covered so completely as to afford no protection for the ploughless fallow.

The one-way disk, perhaps is the best implement for cultivating fallows that are to be ploughed later. Also it can be made into a lister by removing most of the disks.

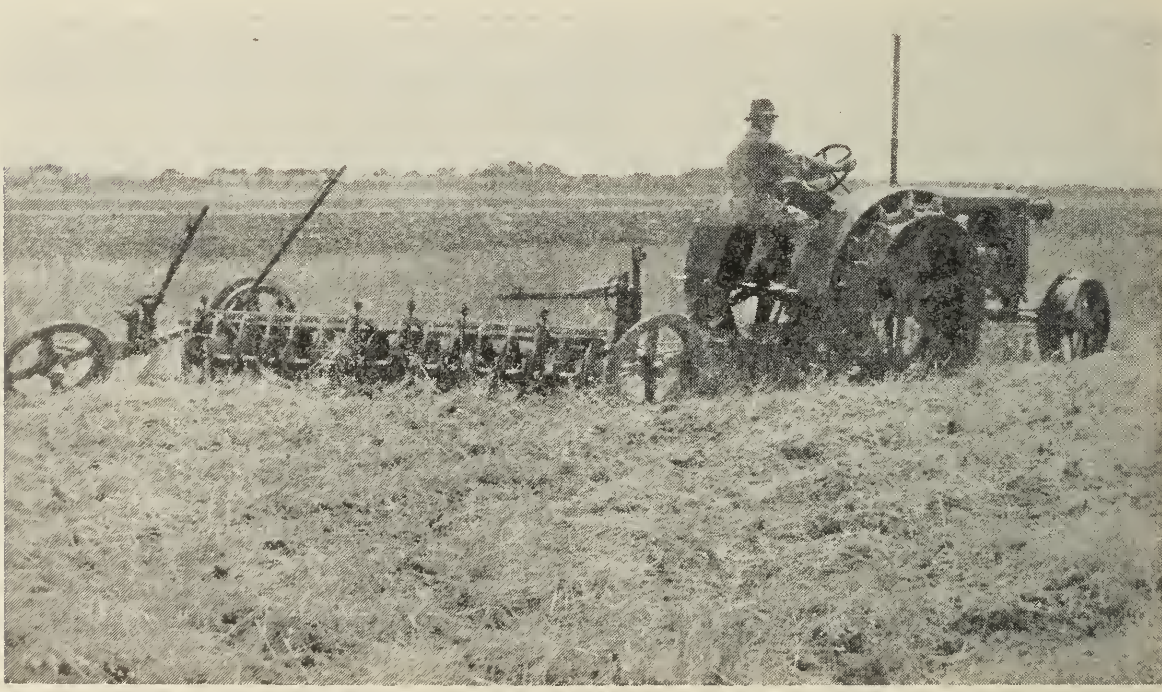
Rod Weeder.—The rod weeder is an effective weeding implement where soil drifting is feared and where conditions are satisfactory for its operation such as level fields, friable soil and relative freedom from stones, as it leaves the surface of the soil undisturbed. This implement is used chiefly on summerfallow after the cultivator or one-way disk. The use of the cultivator and rod weeder forms a very satisfactory practice for destroying weeds and maintaining a protective covering of trash on the surface of the soil where blade cultivators are not used or it can be used for the subsequent stroke after blading if there is not too much trash. The rod weeder does not create a lumpy surface, it merely preserves an existing condition of the surface soil if run about three inches deep. When operated at or near the surface it may pulverize the soil. On some soils the rod weeder is also used extensively to eradicate weeds on ploughed summerfallows and in certain areas also for spring cultivation of summerfallow prior to seeding.

Disk Harrow.—While an excellent implement for shallow cultivation and the preparation of newly broken land, the common disk harrow is not an effective implement for destroying well rooted weeds and probably pulverizes the surface of cultivated soil to a greater extent than other tillage implements if the soil is dry. Considerable judgment should be exercised in its use to minimize soil drifting. The disk harrow cannot be advocated for use on ploughless summerfallows under most conditions. It may be used to advantage, however, for spring disking of summerfallow land that is to be ploughed later, or to cut up a growth of Russian thistle to facilitate the use of the cultivator. This implement is useful for temporarily checking winter and early spring drifting, when only the top soil has thawed, and is also used extensively for spring disking of stubble land in preparation for seeding. On some clay soils where a duck-foot cultivator fails to scour, a single disk set at a moderate angle is also used in preparing fallow land for seeding.

Spike Tooth Harrow.—Considerable care should be exercised in the use of this harrow, particularly on dry soil, to avoid creating a pulverized smooth surface. The harrow may be used, however, under certain conditions to puddle wet soil and to roughen it to form some protection against possible drifting. This operation may be performed in the winter or early spring while the snow is melting. This puddling process has saved many fields from drifting. Similarly, seeded fields that are wet or crusted may be protected temporarily by harrowing to form a cloddy condition either by breaking up the crust or by puddling the wet soil. On dry, friable soils it is not advisable to use the spike tooth harrow.

Seed Drills.—Although the standard types of seed drills were not designed specifically for use in the control of soil drifting, it is possible to adjust these implements to assist in this purpose. In cases where the soil is readily pulverized it is advisable to disconnect the covering chains when seeding with the disk seeder. Some farmers have reported satisfactory results from the use of a hoe

The rod weeder is a very useful implement for destroying weeds on summerfallow land. The soil should first be loosened by the plough or cultivator, the latter implement being used for the final operation for the season. The rod weeder cannot be used in very stony land.



The one-way disk can be used in many cases to displace the plough. It is useful in heavy stubble as much of the stubble is left partially buried at the surface where protection against soil drifting is provided. In short stubble the use of a duck-foot cultivator is preferable as the one-way disk may bury the stubble completely. Unless very weedy, stubble should not be burned in districts where soil drifting may occur.

drill. This implement performs the function of a cultivator as well as seed drill and leaves the soil slightly ridged. The pulverizing action of the hoes upon the surface soil is also much less than that of the disks.

HARVESTING MACHINERY.—The kind of machinery used for harvesting may definitely influence the success or failure of controlling drifting. If a combine, header or header and barge is used, much longer stubble will be left to provide material for a trash cover on the succeeding year's fallow than if the field is cut with a binder. From the standpoint of controlling soil drifting, therefore, it is preferable to use the combine or header for cutting a light crop where it is desirable to leave the maximum amount of stubble for trash protection. If the binder is used it may be advisable to cut the stubble as high as practicable.

SOIL DRIFTING AND WEED CONTROL

The summerfallow, in addition to conserving soil moisture, provides an excellent opportunity for weed control. With the land free of crops it is possible to secure effective control of weeds by repeated cultivation. Unfortunately frequent cultivation of the soil increases the drifting hazard. On the other hand, weeds must be controlled if soil moisture is to be conserved. Obviously the soil requires careful treatment under these conditions if drifting is to be avoided, weeds controlled and moisture conserved.

Surrounded by mounds of drifted soil and choked with sand it has been impossible to move this threshing equipment which has had to be abandoned.

In cases where drifting is likely to occur or is already in progress some form of tillage has to be given to create a lumpy or a ridged surface to resist the wind. Ordinarily, however, the purpose of tillage is to control weeds, and for this purpose it is desirable to use an implement that would destroy all existing weeds preferably in one operation. At the same time it is important that the soil be left in a condition that would best resist the wind. The type of implement to

use would depend on the condition of the soil and the amount of stubble present. The relationship between machinery and effective weed control is discussed in another section of this bulletin.

The usual practice for the eradication of perennial weeds is to maintain a so-called black fallow. By means of repeated cultivation the shoots of such weeds as Canada thistle and perennial sow thistle can be prevented from making their appearance and the root systems of these weeds are in time destroyed. It is essential that cultivation be done frequently and in a very thorough manner. Unfortunately frequent tillage of a black fallow to control perennial weeds generally pulverizes the soil to such an extent that serious drifting may occur. On medium textured soils where there is danger of drifting it may be advisable to handle the field as a ploughless fallow until fall and then to list deeply enough to create a roughened, lumpy condition.

Heavy clay and sandy soils, however, become pulverized in spite of tillage to form a lumpy condition. Where perennial weeds are present on such soils and where drifting may occur as a result of frequent cultivation of the summerfallow, it is advisable to introduce a partial summerfallow. Land to be summerfallowed by this method may be sown early and at a heavy rate to oats for green feed, an early maturing barley, or in the previous autumn to fall rye. These crops are harvested early and the land surface worked and kept black until fall according to the ploughless fallow method outlined on page 19. With this method perennial weeds are controlled and soil drifting prevented if sufficient trash is left on the surface.

The control of annual weeds such as Russian thistle, mustard and wild oats, where the hazard of soil drifting exists, is not as difficult as the control of perennial weeds.

Some annual weeds may be utilized to control soil drifting without any serious loss of soil moisture. The heavy clay soil around Regina is infested with wild mustard. When this weed is allowed to produce a small growth on summerfallow in the fall it acts as a very effective barrier against the action of wind on the soil even after the weeds have been killed by frost. Severe drifting in the spring on many fields in that district has been definitely traced to be due to tillage of the summerfallow after September 1.

On light and medium textured soils in the drier areas of the prairies, growth of Russian thistle on summerfallow is often left to give a certain amount of protection from drifting. However, in many cases of severe soil drifting, fields may become practically ruined by sparsely scattered, large Russian thistles trapping the drifting soil and forming large mounds throughout the field.

Surface cultivation in the preparation of summerfallow land is more effective than ploughing in the eradication of annual weeds from the surface soil. This method has the advantage, moreover, of leaving the stubble on the surface so as to check soil drifting.

It is advisable to work the land in the spring in order to kill all weed growth just before a crop is sown. The reader as referred to section "Spring Treatment of Summerfallow" for suitable methods of eradicating weeds and of maintaining a soil condition that would resist the wind. Control of weeds and soil drifting is not difficult on stubble land, unless the stubble is burned off, in which case drifting may be very serious.

In regions where grasses and clover can be grown successfully in crop rotations, they may be quite effective in controlling many weeds and in preventing soil drifting.

SOIL DRIFTING AND INSECT CONTROL

By C. W. Farstad and L. A. Jacobson, Dominion Entomological Laboratory, Lethbridge, Alberta.

The damage by wheat stem sawfly (*Cephus cinctus* Nort) is easily recognized at harvest time by the presence of fallen stems cleanly cut off at ground level. These stems are tunnelled and filled with a sawdust-like material.

At this time the stub of each cut-off plant will contain a whitish sawfly larva, or "grub", approximately one-half inch in length. The grubs pass the winter in the underground portion of the stubs and change to pupae the next spring. Small narrow-bodied wasp-like insects emerge as adult sawflies about mid-June and immediately commence to search for suitable stems of grasses and grain in which to lay their eggs. If stems are nearby, the flies seldom move far, but in the absence of suitable stems they may migrate a mile or more. Most of the eggs are laid in stems which have reached the "boot" or early heading stage.

Early-seeded wheat usually suffers most severely, as most of the stem are at a suitable stage to receive eggs. Wheat seeded after May 24 frequently escapes damage, the stems not being sufficiently advanced to be chosen for egg-laying. The grubs hatching from the eggs feed on the inside of the stem, eventually tunnelling through the nodes. As the stem ripens the grub worms downward, finally girdling it on the inside at ground level, at which point the stem later breaks off.

The common bread wheats and spring rye are most severely damaged, while the durums and fall rye are less susceptible. Oats and flax are immune, and most of the barley varieties recommended in the sawfly area are highly resistant to damage. The previous year's wheat stubble constitutes the main hazard to the wheat crop. Occasionally stands of western rye grass and couch grass are dangerous sources of infestation, since these grasses are original host plants of this insect.

The most obvious loss from sawfly is the fallen stems which are not picked up by the harvesting equipment. Even if every head could be recovered there is still a loss of about two bushels per acre, as a result of the feeding of the grubs inside the stems.

The very nature of the wheat stem sawfly makes it an excedingly troublesome insect in an area where soil drifting is an ever-present problem. Strip farming, with the multiplicity of strip margins exposed to attack by this pest, has greatly increased the actual hazard. In summerfallowing severely infested fields greater care must be exercised to avoid burying the stubble, most of which is lying on the soil surface. A single operation can cover all trash if work is done too deeply or with improperly adjusted machines. This is particularly true in the use of the one-way tiller.

The increased losses caused by this insect have been instrumental, in some instances, in inducing farmers to increase the width of the strip, and some have abandoned strips entirely.

Control measures for the sawfly are relatively simple. The degree of control and the intensity of the program can readily be adjusted to fit the severity of the infestation.

The fundamental principles involved are as follows:

1. Force the sawflies out of a field or groups of fields by growing immune crops. Oats, flax, barley, fall rye or late-seeded (after May 24) common wheat may be used for this purpose.

2. Destroy sawfly by the liberal use of early seeded wheat traps and by shallow tillage.

Traps are an essential part of the sawfly control program. They are the chief means of killing sawflies as well as providing protection for the new wheat crop. All traps must be destroyed about mid-July to kill the sawfly grubs. This can be done by cutting if desired.

3. Protect the wheat crop by:—

(*a*) Seeding wheat only on summerfallow or other land free of overwintering sawfly.
(*b*) Surrounding each field with a bare-strip trap to reduce invasion. (A bare-strip trap consists of at least a rod wide strip of early seeded wheat separated from the main wheat crop by a bare strip of fallow of the same width.)
(*c*) Seeding crops in the best sequence—sawfly traps first, then oats, barley, flax and finally the wheat crop. The wheat crop should not be seeded until the traps are showing green.

4. Salvage sawfly infested wheat by swathing or binding in the late dough stage.

The above recommendations are the fundamental principles of a complete sawfly-control program. In some areas where sawfly has been causing disastrous losses year after year, it is necessary to take emergency measures to reduce the numbers in the shortest possible time. In such areas it may be necessary to grow nothing but immune crops and late-sown wheat. When this is done, additional traps should be seeded on the infested stubble, using three or four separate drill-widths of early-seeded wheat so that the sawflies find readily available host plants. There will then be less tendency for them to migrate to adjacent fields. These traps have additional advantages in that they afford protection against soil drifting and provide ideal locations for poisoning grasshoppers.

Individual farmers have been able to reduce losses on their own farms, but the danger of reinfestation from adjacent fields is great. Therefore, control should be practised on a community basis, with all farmers co-operating to their mutual advantage.

Say stinkbug (*Chlorochroa sayi* Stal) was first found in southern Alberta in 1934. This new insect pest increased very rapidly and, in the period 1938-1941, caused considerable damage to wheat in many districts.

The insect is a large, green stinkbug which feeds on many of the common weeds, particularly Russian thistle, but also sucks the juice from wheat kernels while they are in the "milk" and "dough" stages. This feeding results in reduced yield and quality.

Say stinkbug spends the winter in the adult stage, seeking shelter under weed piles along roads and fields. It has also been found hibernating in the heavy cover on trash-cover summerfallow fields.

Control measures consist in spring burning of weed piles where overwintering insects are abundant and also in burying of insects by ploughing infested fields to a depth of at least 3-4 inches. These control measures should be used with care, since under certain conditions they have a tendency to increase soil drifting.

CROP ROTATION IN RELATION TO SOIL DRIFTING

As both soil and climatic conditions vary considerably throughout the three Prairie Provinces, there is a very marked difference in the growth of various crops in different regions. Over the greater portion of the area the production of grain forms by far the most important and most profitable agricultural activity. Out of a total acreage of 65,230,050 acres in crop, summer-

fallow and new breaking in 1944, as will be seen from Table 3 in the appendix, there were 62,205,650 acres or 95 per cent of the total in grain and summerfallow. The summerfallow, with 19,782,000 acres, constituted 30 per cent of the acreage over the entire region, while in the drier areas it would reach fifty per cent. The summerfallow is an important agricultural practice in these provinces, chiefly as a means of conserving moisture and combating weeds. Unless properly handled, however, the summerfallow, with relatively large areas of uncropped soil, may present an ideal setting for soil drifting. As will be seen from other chapters in this bulletin, the summerfallow should be worked with the greatest possible care and in accordance with the most suitable methods.

Crop rotations in the drier parts of the Prairie Provinces are restricted by the climate. Grain is the only satisfactory and profitable crop which can be produced. Hay and other fodder crops do not yield well under these conditions. The summerfallow is a prime necessity in order to conserve moisture. The most common rotation in the dry areas is the two-year rotation of summerfallow and wheat. Where moisture conditions are somewhat more favourable a three-year rotation of summerfallow, grain and grain may be more profitable. These rotations should be arranged in strips and in most regions surface worked in order to control drifting.

Where livestock as well as grain are produced, it may be desirable to seed part of the cultivated land to crested wheat grass and leave it in grass for a few years until a good sod is formed before breaking it again for grain farming. This method seems preferable in dry regions to the customary method which is used in the more humid regions of seeding down each year a small acreage of grass and ploughing the sod in about two or three years. Brome grass may be used in localities where moisture conditions are favourable to its growth but brome has not proved as satisfactory as crested wheat under extremely dry conditions and does not form as dense or resistant a sod under any condition. Sweet clover has not proved to be of much value as a sod forming crop. The roots of alfalfa are much more resistant to decay. Western rye grass (slender wheat) and timothy provide a fairly resistant sod. Crested wheat grass is outstanding in leaving a very resistant sod, but it is adapted more especially to the drier regions.

On sandy soils which have been found to be extremely susceptible to soil drifting the summerfallow to a very large extent has been abandoned in the dry regions. On such soils the summerfallow conserves very little moisture and hence fails to give much larger yields than where grain is grown after another crop of grain. In such areas, also, Russian thistle is about the only weed of very great importance and it can be controlled by cultivation just before spring seeding. Various cropping methods have been attempted under these conditions. Sometimes continuous grain is grown, either wheat or fall rye, or wheat alternated with fall rye. Sometimes a part of the land, instead of being summerfallowed, is left uncultivated and is allowed to grow up in weeds. The following spring this land is seeded to wheat, the assumption being that the trash will hold snow and provide some moisture at least in the spring. On light soils somewhat less susceptible to drifting the summerfallow is incorporated into a three-year rotation of summerfallow, fall rye and wheat. Objections may be raised against this rotation in that the fall rye may volunteer in the following wheat crop. If this objection is overcome by seeding the fall rye after the wheat crop, then the summerfallow is left exposed to the danger of soil drifting.

However, it is very questionable if light soils in dry regions should be used for the production of grain. They are really submarginal soils for grain production. They should be removed from cultivation and seeded to crested wheat grass being used either entirely for ranching or in a farm ranch set up. In this way the better soils may be utilized for grain and the less productive soils for grazing, being preferably seeded to a mixture of crested wheat grass and alfalfa.

In southern Alberta winter wheat is grown to some extent both on summerfallow and after spring wheat. Where winter wheat is seeded on summerfallow the fall growth affords some protection against drifting, but as seeding must be delayed until the first of September in order to avoid root-rot injury, growth in the fall is usually not sufficient to ensure protection against drifting, especially in large unstripped fields. If a good fall growth is obtained it may furnish sufficient protection, however, for strips ten or twenty rods wide. Where winter wheat is seeded into the stubble of a preceding crop of wheat, soil drifting, of course, is completely prevented.

In the black soil zone, or so-called park areas, where moisture conditions are more favourable, it is possible to modify the strictly grain rotations and introduce mixed farming rotations containing crops other than grain. Such rotations allow for a certain proportion of the land to be seeded each year to mixed legume and grass for hay or pasture, and in the warmer and moister regions to corn or other summerfallow substitutes. The growing of these crops divides the farm into smaller fields and assists in the solution of the soil drifting problem. Moreover, they provide a much more effective control of weeds and promote larger yields of grain crops. Full advantage should be taken of these crops where they can be grown successfully. Even in the black soil zone soil drifing may occur unless preventive measures are employed. It is unwise, therefore, to leave large areas of land unprotected.

For more detailed information regarding the choice of rotations suitable to the various regions on the prairies, the reader is referred to Publication 761 "Crop Rotations in the Prairie Provinces", published by the Dominion Department of Agriculture, or to the Superintendent of the nearest Experimental Farm.

The following examples of some mixed farming rotations may be suitable for different areas:

Four-year Rotation

1st year—Fallow or intertilled crop, manure
2nd year—Wheat, seeded down
3rd year—Hay, plough in July
4th year—Coarse grain.

This rotation has the disadvantage that one year in hay or pasture is not sufficient to control wild oats. Pasture would have to be provided from some other area.

Six-year Rotation

1st year—Fallow or intertilled crop, manure
2nd year—Wheat, seeded down
3rd year—Hay
4th year—Hay or pasture, plough in July
5th year—Wheat
6th year—Oats or barley.

A mixture of alfalfa and grass provides a satisfactory hay and pasture crop in many black soil regions.

Eight-year Rotation

(may be arranged on four fields)

1st year—Fallow or intertilled crop, manure
2nd year—Wheat
3rd year—Barley
4th year—Hay
5th year—Pasture
6th year—Pasture in May, break in June and summerfallow
7th year—Wheat
8th year—Oats.

This eight-year rotation may be located on four fields by grouping the 1st and 5th years of the rotation in one field, 2nd and 6th years, 3rd and 7th years and 4th and 8th years in three other fields. Considerable fencing may be eliminated by this arrangement. As some difficulty may be experienced in seeding down with the second crop of grain after summerfallow, special precautions should be followed in order to avoid failure.

OTHER METHODS OF SOIL DRIFTING CONTROL

In addition to the methods of soil drifting control already mentioned in this bulletin there are several others which have been tried by some farmers throughout the prairies.

Intertilled crops such as corn, sunflowers, or rows of grain have been grown in the more humid areas and have been reported to have given more or less effective control. These crops are generally used as substitutes for the summerfallow. It is found that weeds are generally more difficult to control than by the usual summerfallow method already described in this publication. Intertilled crops such as these also involve a greater amount of field work. In the drier sections of the prairie they use up so much of the limited amounts of soil moisture that serious reductions in the yields of the succeeding crop generally result. Throughout most of the prairie region they are, therefore, of little practical value.

A distinct disadvantage in intertilled crops is that the cultivations required to control weeds pulverize the soil between the rows and when the crop is harvested drifting may start. This is especially true on corn and sunflower fields that have been cut. The stubble furnishes disappointingly little protection and drifting is often more severe than on fallow. Such fields should be cultivated after harvest.

Some farmers have tried the method of sowing crops such as corn on summerfallow in single rows about two rods apart with the purpose of breaking the wind and trapping snow in the winter. The crop is sown in June after a summerfallow has been worked once or twice to destroy weeds. The spaces between the rows are cultivated in the usual manner throughout the season, while the crop itself is not harvested, but left standing in the field until the following season. In the spring the land is worked at right angles to the rows and sown to grain. Corn has one disadvantage in that after it has been killed by the frost in the fall it is broken down rather easily by the wind. Early seeding produces larger and stronger plants but it also results in greater moisture depletion. Sunflowers stand well over winter but consume too much water to produce profitable results.

The use of a snow plough on summerfallow for the purpose of banking it into ridges to accumulate more snow and prevent soil drifting has been claimed by some farmers to be quite effective. The limitation of this practice in the drier areas of the prairies is the lack of snow. Much of the snow often blows off the summerfallow before it is possible to bank it into ridges, while under the action of mild days and cool nights the changing of snow to ice precludes the use of this method. In areas with higher winter precipitation and in those which are not affected by chinook winds, this practice may be expected to have some application in conserving moisture and controlling soil drifting.

RECLAIMING DRIFTED FIELDS

In comparatively mild cases, drifted fields on loam or clay soils may be reclaimed by employing almost any method described under "Emergency Measures". The purpose is to create a lumpy or ridged condition of the surface

that would check the movement of soil for such period of time as would permit sufficient growth of a crop to give the necessary protection. The one-way disk seeder with packer attachment, the furrow drill, or the mould-board lister may be used to advantage, depending on the severity of conditions.

The one-way disk should be set to penetrate deeply enough to bring moist soil from below. This will create a firm, somewhat lumpy seed-bed and would continue to resist the wind for some time. In case there is danger from soil drifting before the crop is established, lister furrows may be placed at intervals of 1 to 4 rods depending on the seriousness of the situation.

Where the loose soil surface has been removed by wind, it may be possible to get a protective crop established by single disking when the soil is wet and then seeding immediately. A single disk drill is effective in penetrating firm soil and in throwing up sufficient clods to furnish protection against drifting. The field should be watched closely, however, and plough or lister furrows should be placed at intervals as soon as any part of the field shows signs of starting to drift.

The furrow drill may be used for more severe cases of drifting. This implement brings lumps to the surface, broadcasts and buries the seed, and at the same time leaves the land in a ridged condition. Lister furrows may be ploughed at narrow intervals should drifting threaten before sufficient plant cover is established.

Another method is to alternate very narrow listed strips with similar ones sown to wheat or rye in the usual fashion. When sufficient growth of crop has been attained the lister furrows are in turn also sown to grain.

Drifting sands are much more difficult to handle and constitute a special reclamation problem. Areas of drifted sand are generally very rough and hummocky due to accumulation of sand into weed clumps and other obstructions. Experience has shown that levelling prior to reclamation increases the difficulty of stabilizing the soil and is unwarranted in most cases. Implements used in reclaiming sandy areas tend to level the ground considerably and usually sufficiently to enable subsequent seeding and harvesting of grass or other crops.

Reclaiming badly drifting sandy areas is best accomplished under conditions that favour the minimum number of tillage operations. It is advisable not to attempt reclamation early in the spring but to delay the work until June. During this period winds are less severe, rainfall is generally higher, and germination of the crop is much quicker.

The furrow drill and the mouldboard lister have been proved very useful for reclaiming badly drifting sandy land. The furrow drill is quite satisfactory where not too great accumulations of sand are encountered. On deep accumulations, the ridges created may not be able to withstand the wind and it would be necessary therefore to establish deep lister furrows at regular intervals to check the drifting. Complete control of drifting is readily secured where it is possible to turn up some of the subsoil. Where it is impossible to turn up the subsoil the lister is not so effective but will help to prevent the sand from spreading on to adjoining areas.

Crops seeded at the bottom of the lister furrows are generally too poor to offer much protection. The crops may be seeded with other implements and the lister may be used merely for trapping the drifting soil. A more desirable method, however, is to put a seeding attachment on the lister to broadcast the seed over the entire area. Usually sufficient seed germinates on the ridges to offer very effective protection against the wind.

Straw or manure where available, can be scattered, after seeding, over limited areas of sand or drift piles that are too deep for listing to be effective or where it is not desirable to make deep furrows. If straw is used, it is safer to run over it with

a single disk after scattering. This anchors the straw so that it will not be blown off by a sudden gust of wind. If the wind rises gradually, enough soil will move into the straw to anchor it without disking.

Spring rye has been found most satisfactory for seeding badly drifting fields, for it makes a quick growth, maintains itself under quite dry conditions, and is not so readily eaten by grasshoppers as some other grains.

As soon as a good vegetative cover is established, badly drifted sandy areas should be sown and kept permanently in grass. Crested wheat grass has given the best results for this purpose in dry areas and when once established it forms a dense sod and maintains itself through long periods of drought.

Crested wheat grass should be sown shallow, from half to one inch in depth; and preferably mixed with alfalfa. The rate of seeding in dry areas should be about 5 pounds of grass and 2 pounds of alfalfa per acre. Best results are obtained from seeding in late August or early September if moisture conditions are favourable for germination. If the soil is dry, however, it is best to delay seeding until late fall in order that seed may germinate early in the spring and take advantage of the spring moisture to develop the seedlings sufficiently to carry them through the dry weather of the first summer. If weather permits, the grass may be sown in March.

Brome grass is used effectively for regrassing where moisture conditions are satisfactory. Where quack grass prevails, this plant usually occupies abandoned lands after drifting has been stopped.

PROTECTION OF FIELD AND FARMSTEAD BY SHELTERBELTS

No discussion on the subject of soil drifting control would be complete without reference to protection of the farmstead and particularly the farm home. Many farmsteads are now provided with efficient shelterbelts, but the problem of keeping dust out of the homes still awaits solution. Observations have shown that drifting soil is effectively checked in its movement across unbroken prairie land even though the vegetative cover is quite sparse. It is suggested, therefore, that wherever possible a strip of land, at least 20 rods wide, be seeded down as a permanent pasture on the windward side of the home. This pasture area should encircle the shelterbelt, or at least extend along the sides exposed to the

Drifting soil and severe droughts have ruined many farmstead shelterbelts. Proper precautions should be taken to protect shelterbelts against drifting soils. This may be accomplished by means of trap hedges or rows of sunflowers on the windward side.

most frequent winds. A suggested arrangement will be found in the charts on pages 15 and 17. Such provision, of course would not entirely check the infiltration of dust into farm homes, but if coupled with carefully conducted control measures on the cultivated fields would aid materially in lessening the discouraging effect produced in farm homes by severe dust storms.

Further protection in addition to that provided by the farmstead shelterbelt can be secured by planting caragana to form a hedge around the outer edges of the pasture area. Still further protection of course would be secured by the establishment of caragana hedges around the whole cultivated area. The possibilities in this scheme, however, have not been thoroughly explored. In dry areas where soil drifting is most prevalent, hedges are difficult to establish. Russian thistle and other tumble weeds become caught in the hedges and result in the collection of sufficient drifted soil to frequently smother the hedges. Such hedges, however, afford protection for the farmstead shelterbelt against weeds and drifting soil. As caragana requires several years in which to develop, immediate protection may be provided by seeding several rows of sunflowers. The heads may be removed and the stalks left standing over winter.

Measurements have shown that the reduction of wind velocity on the leeward of a shelterbelt extends to a distance equal to about 15 to 30 times the tree heights, depending on wind velocity. The higher the velocity the greater is the sheltering effect to leeward. The reduction in velocity is greatest near the shelterbelt but gradually becomes less with distance to leeward. Because the reduction of velocity is so gradual and the nature of the wind so complex a very definite limit of influence cannot be determined. Under average conditions, a 50 per cent reduction in velocity occurs at about 8 tree heights to leeward.

Field shelterbelts can be established only with great difficulty in the brown soil zone, which includes southeastern Alberta and southwestern Saskatchewan. Elsewhere they are established with less difficulty and are quite suited to the park and wooded regions. Caragana may be established in dry regions but requires great care particularly during the initial stages of growth.

Assuming that caragana is 12 feet high, belts would have to be placed apart not over 30 times this length, or 25 rods apart, to give reasonable protection against soil drifting. Under these conditions drifting may occur for some distance on the windward side of the belts and it would be necessary therefore to establish a heavy trash cover or a cloddy or ridged soil condition to prevent the drifting. Tree belts can be placed farther apart, depending on the relative conditions favouring tree growth.

The work of C. G. Bates of Minnesota shows that a series of belts placed at regular intervals of 20 or 30 tree heights do not have any greater reduction in wind velocity than belts of the same kind placed independently. This is because a single barrier not only shows a greater reduction in miles per hour with a high wind velocity than a low velocity, but actually a greater percentage reduction. There seems to be little likelihood that the velocity of the wind anywhere within large shelterbelt plantations would be substantially less than the velocity under the same soil conditions, height, and distance to leeward from the nearest single belt in open country.

Soil samples collected in the vicinity of shelterbelts in the spring have shown an increase in soil moisture for a distance of 25 to 150 feet. The area of increased soil moisture corresponds on level land to the area covered by the snow drifts.

For information regarding the establishment of hedges and shelterbelts and supplies of necessary material, the reader is invited to communicate with the Dominion Forest Nursery Stations at Indian Head, Sask. and Sutherland, Sask.

An uncertain future lies before this splendid shelterbelt. Drifts of soil three feet deep are lodged within its twelve-foot width.

Anemometers placed at various distances away from a shelterbelt indicate a definite reduction in wind velocity for a distance to leeward equal to 20 to 30 tree heights.

COMMUNITY ACTION AND LEGISLATION

While individual effort is usually very effective in controlling soil drifting and every farmer should adopt the best known control measures on his own farm, the most successful results will undoubtedly follow the adoption of community action. The importance of this community action will be readily understood from the fact that an area of unhindered, drifting soil usually expands very rapidly. Moving particles of soil are not always brought to rest by collision with stationary soil particles and in many cases the latter are caused to join in a general movement under the influence of high winds. The most carefully planned and executed control measures may be entirely ruined if the soil has to withstand the combined action of wind and drifting soil from adjoining unprotected areas. These facts show the necessity for community action if a maximum degree of success in the control of soil drifting is to be obtained. While the control of drifting on any farm is primarily the concern of the individual farmer, his success may be aided or hampered by the action of his immediate neighbours. Organizations have been formed in a number of places on the prairies to promote community action in the control of soil drifting and some excellent progress has been made.

Drifting soil not only covers fences but in many cases very seriously interferes with highway traffic.

In order to prevent losses to neighbouring property by unprotected summerfallow, the Legislative Assembly of the province of Alberta passed an act in 1935 known as the "Control of Soil Drifting Act." This Act places the responsibility on the owner of the land for damage done to adjacent property by soil drifting from his farm, unless he has used drift control measures as prescribed in the Act. No claim for damages may be made by any person, however, unless the claimant himself is complying with the Act in regard to soil drifting control measures. The Act came into force on the 1st day of March, 1936. The following clauses indicate some of the measures which may be adopted to prevent damage to adjacent property and thereby avoid the penalties imposed by the Act:—

Clause 2

"It shall be the duty of the occupier of land which is being summerfallowed to till the same in such a manner as to prevent soil on any part of the summerfallowed land from drifting so as to cause damage to adjacent land and property.

Clause 3

"The occupier of any land which is being summerfallowed shall be deemed to have discharged the duty imposed upon him by this Act if each quarter-section upon which land is being summerfallowed is cultivated according to any of the methods following, namely:—

(*a*) By summerfallowing and cropping the land in alternate strips not exceeding 20 rods in width approximately at right angles to the prevailing direction of wind liable to cause soil drifting, or

(*b*) By surrounding all summerfallow land with a strip of land of at least 30 rods in width cultivated in three strips paralleling the edge of the summerfallow of which the inside and outside strips are each at least 10 rods in width and are either under a grain crop or in stubble, and the remaining strip is summerfallowed, or

(*c*) By surrounding all the summerfallowed land with a strip of land of at least 30 rods in width paralleling the edge of the summerfallow which is under a growing crop of grain or which is in stubble, or

(*d*) By seeding upon the land a covering crop of grain sown not later than the tenth day of August, using for that purpose not less than 20 pounds of seed per acre on all of the land which is under summerfallow, or by seeding the land to fall wheat or fall rye on or before the first day of September, or

(*e*) By maintaining a strip of natural or planted tree growth at least 3 rods in width within 40 rods of and along the whole of each boundary of the property."

The Legislative Assembly of the province of Saskatchewan has passed an Act known as "The Soil Drifting Control Act, 1938," which is designed to supplement by legislation the efforts of farmers and groups of farmers to control this problem. The following extracts from this Act indicate the procedure which is to be followed in order to bring it into operation in any municipality in the province:—

Clause 2

"The council of a rural municipality may, and shall on a receipt of a petition signed by 40 resident ratepayers requesting the council so to do, pass a by-law providing for the regulation and control of tillage practices which, in the opinion of the council, are liable to cause rapid soil deterioration by wind erosion.

Clause 3

"(1) A by-law may contain provisions requiring adoption of the practice of strip farming, the growing of cover crops, the providing of trash cover or the spreading of straw or other refuse on cultivated lands, requiring, prohibiting or governing the use of specified kinds of machinery, governing tillage operations and regulating or prohibiting the growing of crops in specified areas.

"(2) The Minister of Agriculture shall provide a draft by-law when requested by the council to do so.

Clause 4

"(1) No by-law shall have any effect until it has been approved by the Minister of Agriculture and submitted to a vote of the electors and appproved by three-fifths of those voting thereon."

Manitoba has "an Act to provide for the rehabilitation of Drought and Soil Drifting Areas in the Province" which gives both the province and municipalities wide powers in connection with land rehabilitation and soil drifting control.

Both the province and municipalities are given power to " . . . to any act or thing contemplated or required to be done under the Prairie Farm Rehabilitation Act (Canada). . . ."

Powers given municipalities to control tillage are shown in the following extracts from the Act:

6. (1) A municipality may, by by-law, provide for the regulation and control of tillage practices which, in the opinion of the council, are liable to cause rapid soil deterioration by wind erosion.

(2) A by-law may apply to the whole of the municipality or any portion designated.

(3) The by-law may contain provisions requiring adoption of the practice of strip farming, the growing of cover crops, the providing of trash cover or the spreading of straw or other refuse on cultivated lands, prohibiting the burning of stubble, prohibiting the cutting or requiring the planting of trees, requiring, prohibiting or governing tillage operations, and regulating or prohibiting the growing of crops in specified areas.

(4) No by-law shall have any effect until it is approved by the Minister and submitted to a vote of the ratepayers of the municipality and approved by three-fifths of those voting thereon.

7. The by-law may provide that the reeve or other designated officer of the municipality may make orders for the purpose of giving effect to the by-law requiring the person occupying any land to do the work specified therein.

8. If the person against whom an order is made fails to comply therewith the council may, by its agent, enter upon the land affected by the order and perform the required work, and if the occupant of the land is the owner thereof, the cost of the work done shall be forthwith added to and form part of the taxes on the land.

9. No order made under Section 7 shall have any effect until it is approved by the Minister or his representative authorized for such purposes by him.

In many instances as this, tumbling weeds have been caught in fences and drifting soil has accumulated to such an extent that both the weeds and fences have been entirely buried.

The promotion of measures to control soil drifting might well be undertaken by community organizations in the Prairie Provinces. While the farmer and his family are the chief sufferers, the inhabitants of towns and cities are also unwilling victims during severe dust storms. Radical changes from present farming practices will not be required. Some changes, however, are absolutely imperative. It is probable that the most effective measures for controlling drifting will include a combination of several methods on individual farms and community action throughout entire districts.

SUMMARY

1. Methods of soil drifting control have been developed that have so fully proved their worth in many years of tests by investigators and farmers that drifting now can be prevented under almost every condition. The following farming program is followed by many farmers with complete success in areas where drifting is severe:

All fields are strip-farmed with strips not over twenty rods wide.

Ploughless tillage is practised on fallows with careful attention to the selection and use of tillage implements so that all stubble and other plant residue is left on the surface as a trash cover.

In late summer, if there is not sufficient trash to protect the soil through the fall, winter, and spring, the fallows are ploughed, seeded to cover crops, or listed. Bare dusty fallows are never subjected to the drifting hazards of the fall, winter and spring seasons.

Sandy soils in dry areas or other lands that are extremely difficult to control are seeded permanently to grass.

Rotations are substituted for fallows wherever feasible, where moisture conditions permit.

Emergency action is seldom required if the above program is followed but suitable emergency methods are employed immediately any drifting is threatened.

2. Emergency methods may have to be employed to control soil drifting that has been caused from improper handling of the fallow or from any other cause. These emergency methods include the following:—

(*a*) Scattering straw or manure.
(*b*) Ridging with the lister or with the duck-foot cultivator.
(*c*) Ploughing furrows about one rod apart at right angles to the direction of the wind.
(*d*) Listing with a disk lister during winter months when the frozen soil becomes bare.
(*e*) Reploughing deeply.

3. New machinery purchased should be selected to meet the needs of soil drifting control. The duck-foot cultivator, listing shovel attachments, rod weeder and the one-way disk are important implements. Blade weeders and other machines especially adapted to control drifting have been devised.

4. The use of crop rotations which include grass and intertilled crops may be used to advantage in regions receiving sufficient precipitation.

5. Properly designed farm home shelterbelts are very desirable for protecting the garden and buildings as well as for creating more pleasant conditions in the home.

6. Community action must be secured for the most effective and permanent control of soil drifting. Several districts have already made excellent progress and there is no reason why every community might not obtain similar satisfactory results.

APPENDIX

In view of the severe drought and soil drifting conditions which sometimes prevail in the three Prairie Provinces, and especially the extreme conditions which occurred from 1931 to 1938, it has seemed advisable to present a series of tables showing the yields of wheat and the precipitation records over a long period of years. With these data available, the reader may study for himself the variable character of the crops and to some extent estimate the future. Undoubtedly, the variable factors of precipitation, yield and price have combined to produce widely different revenues, these fluctuations often extending throughout several years in succession. In dryland agriculture, good and poor years occur at uncertain and irregular intervals making it imperative to prepare in advance for unfavourable conditions.

The three Prairie Provinces of Manitoba, Saskatchewan and Alberta comprise the most important areas devoted to the production of grain crops in Canada. As will be seen in table 3 the acreage of wheat, oats and barley in this region constitutes about 86 per cent of the total acreage of these crops grown in Canada. Large acreages of summerfallow, which is used for grain growing are also to be found in these provinces. Land in grain or summerfallow, especially if not handled properly, may create conditions giving rise to soil drifting.

Crop yields vary widely from year to year and even throughout periods of several years in succession. Saskatchewan suffered most severely during the period from 1929 to 1938. Throughout this ten-year period the provincial average yield of wheat was only 9·5 bushels per acre and in the year 1937 only 2·7 bushels per acre. This may be compared with the previous seven good years which averaged 18·4 bushels with an average over a period of 36 years, from 1910 to 1945, of 14·8 bushels per acre. Alberta experienced its lowest yield in 1918 with a provincial average of only 6·0 bushels per acre while Manitoba had its smallest yield of 9·0 bushels in the rust year of 1935.

These provincial average yields, however, do not reveal the severity of the drought which has occurred as well as the yields in certain crop districts where conditions have been more extreme. A study of the yearly and average yields in individual crop districts, therefore, will show which districts have been most affected and how small the returns have been in some areas. Even these crop district yields are averages over a considerable area indicating that in dry years many farmers in some parts have failed to harvest any crops whatever.

In crop district No. 3 in southwestern Saskatchewan, as will be seen in table 10, with an area of approximately three million acres seeded to wheat, the average yield, over a thirty-year period from 1916 to 1945, has been 12.1 bushels per acre. However, for the ten-year period from 1929 to 1938 the average yield was only 5.7 bushels per acre with an average return of only $3.47 per acre. For the four-year period from 1931 to 1934 the return was only $2.04 per acre. In 1937 the crop over this entire crop district was practically a complete failure; the average yield was only 0.2 of a bushel per acre with a return value of only 21 cents. However, during the previous seven years from 1922 to 1928 the average yield was 19.5 bushels per acre and the average revenue $17.85 per acre. It is clear that very wide differences arise in yield and return per acre not only in individual years, but over a long period of years.

The amount of precipitation in the three Prairie Provinces decreases from Winnipeg, Manitoba as far west as Medicine Hat, Alberta, beyond which there is a progressive increase as far as the foothills of the Rocky Mountains. Wide fluctuations in precipitation occur from year to year, the degree of this fluctuation becoming wider as the precipitation becomes less. Thus, at Winnipeg, in a period of sixty years, where the annual preciptation has averaged 19.88 inches, the

fluctuation has varied from 13.76 inches in 1917 to 27.19 inches in 1898 or a ratio of 1 to 1.97. However, at Medicine Hat, with an average annual precipitation of 13·02 inches the fluctuation has varied from as low as 6·38 inches in 1931 to as much as 25·28 in 1927 or a ratio of 1 to 3·96. At Qu'Appelle, Saskatchewan, an intermediate point, the corresponding relationship between the lowest and the highest annual precipitation has been as 1 to 2.7.

Precipitation is frequently characterized by heavy showers of short duration when much of the rainfall may be lost by run-off. Many showers also are of such small proportions that the moisture they furnish is almost immediately lost by evaporation. Under average conditions moisture is the limiting factor in crop production over extensive areas, particularly on the open plains. When below average moisture conditions prevail crop production is beset by many difficulties of which drought and soil drifting are the most serious. While the records of annual precipitation as presented in this bulletin, or even monthly precipitation figures, do not give a complete picture of moisture conditions, they do provide some information on which to estimate the occurrence of wet and dry years.

A study of the precipitation records presented in this bulletin will show the wide variations which occur from year to year as well as during cycles of several years in succession. Sometimes a single dry year is followed by a single wet year, while at other times groups of wet and dry years succeed each other. A careful examinatioin of these records, over periods up to sixty years duration, does not indicate any permanent change in the precipitation, either increase or decrease. Different localities have different intensities of evaporation as well as different amounts of precipitation together with wide annual variations.

TOTAL ACREAGE AND VALUES OF FIELD CROPS BY PROVINCES

Table 1.—Total Acreages of Field Crops

Province	1915	1927	1932	1939	1944
	acres	acres	acres	acres	acres
Prince Edward Island	481,930	533,463	476,200	479,300	467,000
Nova Scotia	727,260	702,127	536,000	551,900	555,100
New Brunswick	893,800	889,277	907,500	901,600	992,700
Quebec	4,901,760	6,877,900	5,832,100	6,142,100	6,802,900
Ontario	9,391,500	10,305,045	9,224,300	9,086,600	8,535,700
Manitoba	4,843,816	5,968,983	5,866,800	6,863,300	7,284,300
Saskatchewan	13,036,596	19,527,971	22,333,900	20,749,200	23,535,200
Alberta	4,570,918	10,971,761	14,019,000	13,951,400	13,991,250
British Columbia	292,880	395,783	437,700	510,100	568,400
Total	39,140,460	56,172,310	59,633,500	59,235,500	62,732,550

Table 2.—Total Value of Field Crops

Province	1915	1927	1932	1939	1944
	$	$	$	$	$
Prince Edward Island	10,930,400	13,420,800	6,393,000	10,634,000	15,420,000
Nova Scotia	19,536,700	18,597,000	10,206,000	12,659,000	20,313,000
New Brunswick	20,095,600	18,413,500	12,629,000	19,961,000	38,849,000
Quebec	104,683,000	144,273,000	70,382,000	88,376,000	150,753,000
Ontario	207,043,500	255,900,000	113,904,000	149,672,000	214,769,000
Manitoba	92,318,800	82,280,000	28,981,000	58,640,000	147,764,000
Saskatchewan	265,605,700	348,005,000	80,046,900	166,633,000	444,281,000
Alberta	93,514,200	272,343,300	83,331,000	113,190,000	233,622,000
British Columbia	11,625,700	19,501,000	10,714,000	14,365,000	22,287,000
Total	825,370,600	1,173,133,600	416,586,900	634,130,000	1,288,058,000

(Canada Year Book and Agricultural Branch, Dominion Bureau of Statistics)

ACREAGES IN CROP, SUMMERFALLOW, NEW BREAKING AND PASTURE IN THE PRAIRIE PROVINCES AND CANADA, 1944

Table 3

Crop	Manitoba	Saskatchewan	Alberta	Three Prairie Provinces	Total, six other Provinces	Total, ALL Canada
Wheat	2,505,800	13,200,000	6,738,000	22,443,800	840,400	23,284,200
Oats	1,615,000	5,640,300	3,191,600	10,446,900	3,857,300	14,304,200
Barley	2,123,000	2,698,500	1,941,900	6,763,400	527,400	7,290,800
Rye	44,500	397,400	130,650	572,550	75,400	647,950
Mixed Grain	41,800	96,200	50,600	188,600	1,329,500	1,518,100
Flaxseed	167,000	939,000	191,500	1,297,500	25,600	1,323,100
Buckwheat	6,000	....	....	6,000	250,000	256,000
Hay and Clover	431,000	346,400	702,700	1,480,100	8,639,600	10,119,700
Alfalfa	235,000	160,900	249,200	645,100	935,100	1,580,200
Grain Hay	....	....	700,000	700,000	32,500	732,500
Fodder Corn	33,200	7,100	11,000	51,300	422,700	474,000
Potatoes	27,800	41,600	28,700	98,100	436,800	534,900
Roots	2,900	3,800	4,400	11,100	136,100	147,200
Sugar Beets	10,000	....	28,700	38,700	17,200	55,900
Pasture Improved	*455,487	783,901	625,578	1,864,966	6,637,907	8,502,873
New Breaking	33,000	444,100	227,800	704,900	....	704,900
Summerfallow	2,200,000	11,600,000	5,982,000	19,782,000	....	19,782,000
Total area under cultivation	9,931,487	36,359,201	20,804,328	67,095,016	24,163,507	91,258,523
Pasture unimproved*	4,823,515	19,815,940	18,745,520	43,384,975	8,993,261	52,378,236

(Agricultural Branch, Dominion Bureau of Statistics)
* 1941 Census.

Table 4.—Wheat Acreages in Various Years

Year	Manitoba	Saskatchewan	Alberta	Total acreages	
				Prairie Provinces	All Canada
	acres	acres	acres	acres	acres
1910	2,760,371	4,228,222	879,301	7,867,894	8,865,000
1920	2,705,622	10,061,069	4,074,483	16,841,174	18,232,374
1928	2,660,125	13,790,854	6,707,526	23,158,505	24,119,140
1933	2,536,000	14,743,000	7,898,000	25,177,000	25,991,100
1934	2,533,000	13,262,000	7,501,000	23,296,000	23,986,300
1935	2,587,000	13,206,000	7,500,000	23,292,000	24,115,700
1936	2,566,600	14,744,000	7,537,200	24,837,800	25,604,800
1937	2,872,000	13,893,000	7,834,000	24,599,000	25,570,200
1939	3,201,000	14,233,000	8,379,000	25,813,000	26,756,500
1944	2,505,800	13,200,000	6,738,000	22,433,800	23,284,200

WHEAT YIELDS IN THE PRAIRIE PROVINCES

Table 5.—Yield per Acre

Year	Manitoba	Saskatchewan	Alberta
	bush.	bush.	bush.
1910	12·4	15·8	10·3
1911	22·6	20·7	22·3
1912	22·2	19·2	21·6
1913	19·0	21·2	22·7
1914	14·8	13·7	21·0
1915	24·8	25·1	31·1
1916	10·9	16·3	25·0
1917	16·7	14·2	18·2
1918	16·3	10·0	6·0
1919	14·2	8·5	8·0
1920	13·9	11·2	20·5
1921	11·1	13·7	10·3
1922	19·2	20·2	11·2
1923	12·3	21·3	28·0
1924	16·9	10·2	11·0
1925	17·8	18·5	18·0
1926	22·6	16·2	18·5
1927	14·0	19·5	27·4
1928	19·7	23·3	25·5
1929	13·7	10·7	12·0
1930	18·3	13·7	18·6
1931	11·1	8·9	17·7
1932	16·6	13·6	20·4
1933	12·8	8·4	12·0
1934	14·6	8·5	15·0
1935	9·0	10·8	13·2
1936	10·9	8·0	9·1
1937	16·7	2·7	9·4
1938	15·7	9·6	18·6
1939	19·2	17·6	19·5
1940	18·9	17·5	20·8
1941	20·9	11·1	15·1
1942	27·8	27·1	26·8
1943	25·0	15·2	17·1
1944	20·1	18·3	15·7
1945	18·8	11·9	12·5
Average, 36 years	17·1	14·8	17·6

(Canada Year Book and Agricultural Branch, Dominion Bureau of Statistics.)

The province of Saskatchewan, as will be seen from the above figures, suffered most severely from drought and soil drifting from 1929 to 1938. Alberta experienced its most severe droughts in 1918 and 1919 and again in 1936 and 1937. Manitoba had its lowest yield in the rust year of 1935.

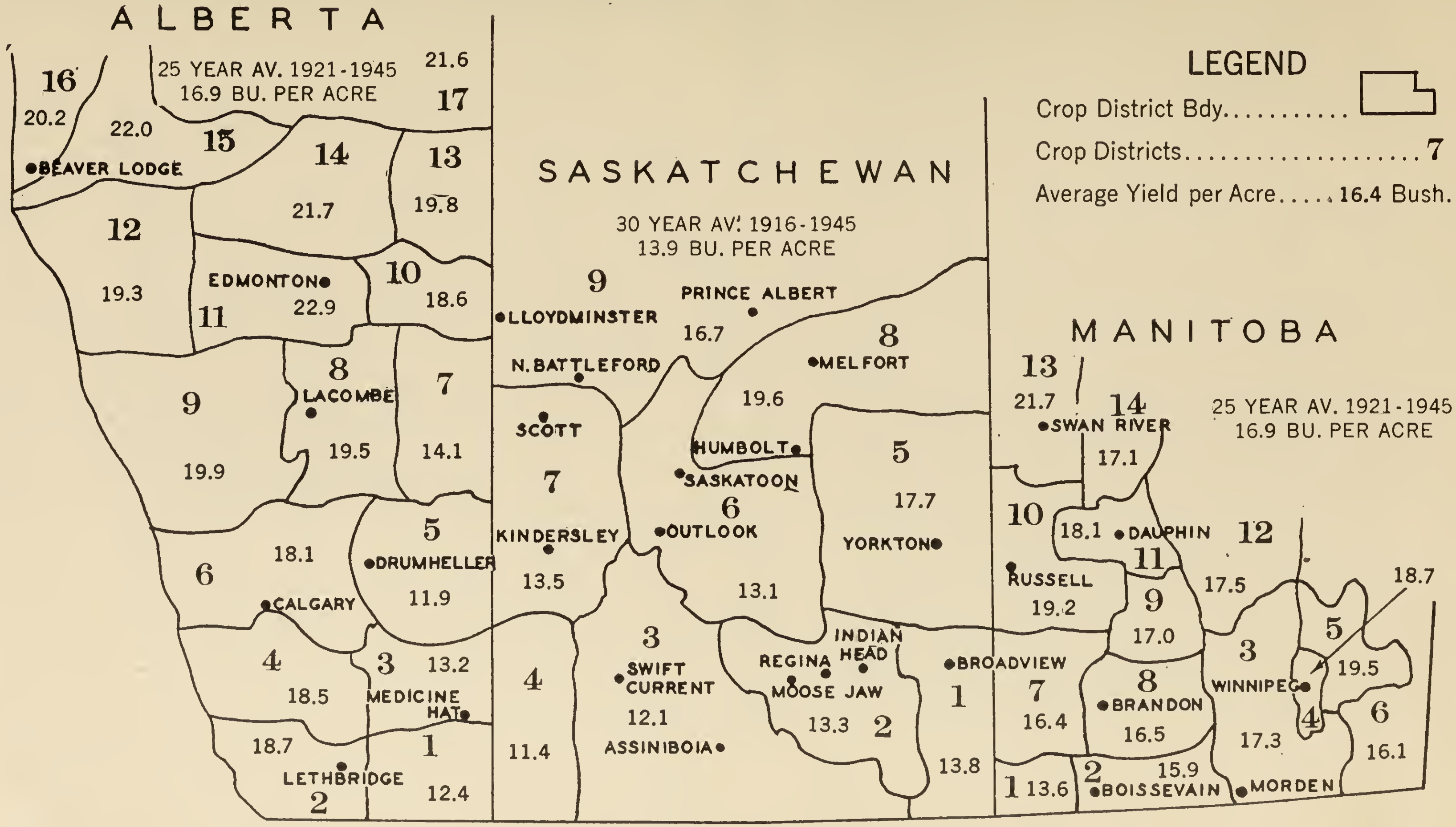
AVERAGE YIELDS OF WHEAT PER ACRE IN THE CHIEF WHEAT PRODUCING COUNTRIES

Table 6

—	Number of Years' records	Average Yield per Acre
		(bush.)
Canada	36	16·1
Manitoba	36	17·1
Saskatchewan	36	14·8
Alberta	36	17·6
United States	69	13·3
Kansas	33	13·0
Nebraska	33	15·0
North Dakota	33	10·2
South Dakota	33	10·3
Minnesota	33	14·0
Montana	33	15·4
India	22	10·9
Russia	15	10·4
Argentina	22	11·3
Australia	22	11·3
Italy	22	17·9
France	22	20·7
England	20	31·4
Germany	20	29·6

WHEAT YIELDS BY CROP DISTRICTS

AVERAGE YIELDS OF WHEAT IN BUSHELS PER ACRE



WHEAT YIELDS IN MANITOBA BY CROP DISTRICTS

Table 7.—Yield per Acre

Year	Crop Districts														Prov. Average
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.
1921	5·7	9·3	11·9	16·9	16·7	9·4	10·9	10·8	12·7	15·6	12·6	11·2	20·3	11·0	11·1
1922	17·7	17·8	19·0	19·8	20·6	20·6	20·3	16·2	16·0	26·5	20·0	22·4	26·0	18·4	19·2
1923	9·8	9·6	9·6	12·9	12·8	11·7	13·5	9·5	10·3	16·7	11·9	12·4	17·9	13·6	12·3
1924	16·4	16·3	19·9	20·0	17·9	15·9	17·1	17·5	14·9	12·9	15·4	9·9	14·5	14·7	16·9
1925	18·5	18·7	18·3	17·8	18·9	13·7	17·1	19·6	15·0	18·3	12·9	14·3	20·0	14·6	17·8
1926	23·1	24·7	22·6	22·6	23·7	16·5	22·5	23·4	18·5	22·5	18·6	13·9	23·6	17·0	22·6
1927	16·7	15·6	10·7	10·8	11·0	11·0	16·5	11·1	10·8	18·5	11·5	11·4	14·0	10·6	14·0
1928	20·7	21·7	16·1	21·8	21·5	16·3	21·0	20·8	20·5	21·6	19·2	19·9	20·4	17·8	19·7
1929	13·2	12·1	14·4	16·5	15·5	14·3	14·1	12·5	12·4	15·2	14·2	14·2	20·2	13·4	13·7
1930	14·2	20·6	19·3	17·6	18·8	17·0	18·3	17·9	16·8	18·8	17·1	17·5	19·2	16·7	18·3
1931	1·7	6·5	13·6	15·7	18·3	14·9	7·5	9·9	11·5	14·6	19·2	15·9	22·0	22·2	11·1
1932	10·8	16·5	15·0	16·4	14·9	13·9	16·1	16·3	16·8	22·3	18·6	19·0	22·7	19·9	16·6
1933	3·5	11·8	13·9	14·5	14·8	14·2	12·2	13·2	14·7	18·7	19·6	15·4	24·4	22·0	12·8
1934	0·6	9·0	19·7	23·3	25·3	17·4	11·3	14·9	18·0	17·7	21·0	19·1	23·7	17·3	14·6
1935	9·2	7·8	11·0	12·1	11·2	9·6	7·1	6·0	5·8	6·5	10·5	8·6	15·0	9·4	8·7
1936	5·0	7·3	13·4	14·0	16·2	11·0	9·0	11·9	13·9	15·9	15·6	14·3	20·5	14·4	10·9
1937	12·4	16·1	21·2	22·0	23·2	18·4	11·9	15·2	18·8	11·7	15·8	19·0	14·6	14·7	16·7
1938	9·8	14·5	16·2	16·2	19·0	16·9	16·4	17·6	17·4	20·7	18·9	17·6	18·4	14·2	15·7
1939	14·6	15·3	20·4	20·4	21·5	18·3	16·4	21·7	23·3	23·4	27·6	26·0	33·5	24·2	19·2
1940	19·9	18·5	20·6	24·2	26·2	21·2	14·0	17·8	22·1	14·9	17·8	13·9	20·7	15·1	18·9
1941	17·6	20·5	20·2	21·2	22·3	20·6	20·0	19·5	22·4	21·5	19·5	19·5	19·5	18·5	20·9
1942	20·6	26·6	28·8	30·8	31·9	25·7	25·9	25·6	27·3	30·5	26·9	28·8	30·0	24·4	27·8
1943	24·5	25·0	24·0	25·1	26·0	20·0	25·0	24·0	25·0	30·0	24·0	26·0	30·0	22·5	25·0
1944	17·8	19·8	17·0	17·7	18·5	17·0	23·4	20·7	19·9	25·3	24·1	24·2	26·5	25·7	20·1
1945	17·4	16·2	16·3	16·9	20·6	17·3	21·9	19·7	22·3	21·7	19·0	23·7	25·9	17·0	18·8
Average, 25 years	13·6	15·9	17·3	18·7	19·5	16·1	16·4	16·5	17·0	19·2	18·1	17·5	21·7	17·1	16·9

WHEAT YIELDS IN SASKATCHEWAN BY CROP DISTRICTS

Table 8.—Bushels per Acre

Year	Crop Districts									Prov. Ave.
	1	2	3	4	5	6	7	8	9	
	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.
1916	8·2	11·7	14·3	18·1	15·4	15·7	18·0	16·9	17·5	16·3
1917	14·9	13·2	12·5	12·2	19·2	14·4	13·2	17·3	13·5	14·2
1918	10·3	12·1	8·1	4·7	16·0	11·8	5·2	21·3	6·8	10·0
1919	9·9	10·6	5·8	3·5	20·3	9·4	6·8	13·0	6·0	8·5
1920	9·3	10·2	11·0	9·9	15·0	8·5	13·8	15·6	17·3	11·2
1921	9·8	11·9	14·1	8·6	16·8	14·5	13·2	22·3	20·3	13·7
1922	23·2	23·2	24·2	18·7	21·2	16·0	12·2	24·2	16·0	20·2
1923	15·1	17·5	21·0	18·0	19·4	22·6	28·0	23·7	27·1	21·3
1924	14·8	12·8	13·9	6·7	10·1	6·3	5·6	8·9	9·1	10·2
1925	17·2	19·3	17·7	9·8	19·9	17·7	21·3	25·3	20·8	18·5
1926	24·0	21·9	16·5	8·8	19·6	12·9	12·5	18·7	16·3	16·2
1927	18·0	17·8	17·3	26·9	20·5	18·9	20·5	19·8	21·1	19·5
1928	20·2	21·8	25·8	27·1	21·9	22·3	24·0	20·9	20·5	23·3
1929	16·1	7·9	6·8	13·2	14·3	10·6	12·1	19·6	13·9	10·7
1930	13·9	11·2	8·4	13·7	16·0	10·9	19·9	24·1	29·3	13·7
1931	4·8	1·8	3·1	5·7	10·6	8·4	13·0	22·0	23·4	8·9
1932	11·9	11·0	8·3	15·7	17·2	11·6	16·9	22·0	20·7	13·6
1933	8·5	12·4	4·0	4·3	23·4	5·6	4·1	16·6	14·4	8·4
1934	4·8	4·8	3·6	4·3	18·1	8·2	8·6	16·7	18·1	8·6
1935	4·3	7·4	11·6	7·1	9·7	13·8	10·6	16·3	14·3	10·8
1936	6·0	9·9	4·7	1·3	17·7	10·6	5·3	14·4	8·1	8·0
1937	4·1	1·4	0·2	0·1	7·7	1·2	1·4	10·6	5·9	2·7
1938	7·8	9·7	6·6	9·5	14·8	8·9	11·2	13·3	8·6	9·6
1939	7·0	9·9	16·6	16·4	21·9	19·3	19·3	27·9	20·0	17·6
1940	16·4	13·6	16·5	19·9	16·3	15·2	22·1	23·5	17·6	17·5
1941	21·1	16·8	7·5	10·0	14·9	7·4	9·5	15·8	11·5	11·1
1942	23·5	25·9	28·1	23·5	27·0	27·9	27·9	28·4	28·8	27·1
1943	23·4	17·8	14·2	5·8	24·1	12·9	8·4	20·6	17·8	15·2
1944	25·7	21·5	16·0	15·1	22·2	21·3	12·9	25·0	24·8	18·3
1945	20·1	15·0	5·8	3·7	21·8	10·9	7·8	24·7	12·1	11·9
Average, 30 years	13·8	13·3	12·1	11·4	17·7	13·1	13·5	19·6	16·7	13·9

WHEAT YIELDS IN ALBERTA BY CROP DISTRICTS

TABLE 9.—YIELD PER ACRE

Year	Crop Districts																	Prov. Aver-age
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.	bush.
1921	9·0	15·0	9·0	15·0	7·0	14·0	9·5	14·0	12·0	12·0	16·0	13·0	18·0	16·0	9·5	11·0	12·0	10·3
1922	8·0	16·0	8·0	16·0	7·0	12·0	10·0	14·0	13·5	9·5	12·0	14·0	12·0	13·5	12·0	11·0	12·0	11·2
1923	18·0	25·0	18·0	30·0	28·0	35·0	28·0	32·0	28·0	25·0	32·0	25·0	26·0	30·0	31·0	26·0	28·0	28·0
1924	4·0	12·0	6·0	14·0	7·0	12·0	6·0	14·5	12·0	16·0	22·0	17·0	16·0	20·6	16·0	14·0	15·0	11·0
1925	10·0	18·0	12·0	20·0	17·0	18·0	19·0	21·0	17·0	19·0	26·0	23·0	17·0	23·0	22·0	16·0	18·0	18·0
1926	7·5	18·0	11·0	25·0	16·0	19·0	19·0	23·0	18·0	16·0	25·0	22·0	12·0	18·0	29·0	20·0	25·0	18·5
1927	30·0	28·5	31·2	30·2	27·7	26·0	25·3	25·0	20·0	26·8	29·0	22·4	25·7	27·8	34·0	33·2	35·0	27·4
1928	27·0	24·5	24·5	24·7	20·8	26·5	20·5	22·2	19·3	22·0	26·7	20·0	19·5	23·0	19·5	19·8	12·7	25·5
1929	13·8	22·3	11·0	15·8	6·2	9·6	4·9	10·8	13·1	10·5	17·6	15·8	14·0	19·3	23·3	20·4	17·4	12·0
1930	10·1	23·7	11·2	24·4	10·9	16·6	20·2	18·9	26·0	28·9	28·0	29·1	30·9	31·4	30·3	30·5	32·2	18·6
1931	7·8	14·1	10·0	15·9	7·6	17·3	16·1	23·7	26·8	23·8	28·7	23·9	24·3	27·1	26·6	21·7	23·3	17·7
1932	15·5	18·9	16·0	22·2	16·8	25·2	18·5	21·3	26·8	21·9	25·4	24·4	25·1	26·6	23·9	18·5	15·7	20·4
1933	12·1	9·7	7·3	9·4	3·1	13·2	11·1	16·6	21·6	18·7	22·2	18·8	22·1	19·9	21·2	19·8	19·0	12·0
1934	14·5	20·6	9·2	15·4	4·6	13·9	10·3	14·0	16·2	21·6	23·6	21·9	23·6	21·3	26·6	25·8	26·8	15·0
1935	13·1	14·0	11·4	13·4	9·9	19·0	8·8	19·1	19·8	12·3	13·2	5·5	12·4	10·6	16·1	17·3	23·6	13·6
1936	4·2	6·8	8·2	5·9	2·9	7·2	4·9	13·1	17·3	12·0	18·5	18·5	16·0	16·9	21·5	26·4	23·4	9·1
1937	4·7	18·1	9·0	10·9	2·0	8·5	2·7	10·6	17·9	11·5	13·9	16·5	14·9	13·8	15·4	13·0	15·9	9·4
1938	15·7	28·0	15·7	18·8	14·3	18·4	15·3	24·9	21·3	18·9	23·5	21·3	14·6	16·6	17·1	10·7	17·0	18·6
1939	12·8	17·2	14·8	20·0	17·1	23·9	13·9	21·8	23·4	17·1	26·4	17·9	24·6	27·3	19·4	25·2	24·3	19·5
1940	13·0	21·8	20·7	23·0	20·5	23·2	18·0	20·8	23·7	19·4	27·4	21·2	20·3	23·9	23·3	26·6	26·1	20·8
1941	16·5	20·7	13·3	16·0	7·3	14·6	5·9	14·0	23·4	14·3	20·2	20·8	19·0	22·6	23·9	23·3	22·5	15·1
1942	24·5	29·6	22·9	31·2	25·0	27·5	22·4	29·7	24·2	27·5	31·1	21·6	27·0	27·9	23·3	23·2	26·2	26·8
1943	8·4	16·0	11·2	14·0	8·8	19·0	17·5	22·1	16·9	26·3	26·4	17·1	23·8	25·9	21·1	21·8	27·4	17·1
1944	5·2	13·5	6·5	15·4	4·9	17·2	17·4	23·8	22·0	22·8	23·6	16·8	24·0	22·9	25·0	15·9	24·0	15·7
1945	5·9	18·8	11·5	15·9	6·2	15·4	8·9	16·9	18·0	10·2	15·3	15·1	11·4	16·2	18·6	13·3	16·9	12·5
Average, 25 years	12·4	18·7	13·2	18·5	11·9	18·1	14·1	19·5	19·9	18·6	22·9	19·3	19·8	21·7	22·0	20·2	21·6	16·9

VARIATION IN YIELD AND VALUE OF WHEAT CROP PER ACRE THROUGHOUT A 30-YEAR PERIOD FROM 1916 TO 1945

Table 10.—Crop District No. 3, Saskatchewan

Year	Yield per acre	Price per bushel	Return Value per acre
	bush.	$	
1916	14·3	1·28	18·30
1917	12·5	1·95	24·37
1918	8·1	1·99	16·12
1919	5·8	2·32	13·46
1920	11·0	1·55	17·05
1921	14·1	0·76	10·72
1922	24·2	0·85	20·57
1923	21·0	0·65	13·65
1924	13·9	1·21	16·82
1925	17·7	1·10	19·47
1926	16·5	1·08	17·82
1927	17·3	0·97	16·78
1928	25·8	0·77	19·87
1929	6·8	1·03	7·00
1930	8·4	0·47	3·95
1931	3·1	0·38	1·18
1932	8·3	0·35	2·91
1933	4·0	0·47	1·88
1934	3·6	0·61	2·20
1935	11·4	0·60	6·84
1936	4·7	0·88	4·14
1937	0·2	1·04	0·21
1938	7·0	0·58	4·06
1939	18·1	0·51	9·23
1940	16·2	0·52	8·42
1941	8·0	0·50	4·00
1942	25·6	0·65	16·64
1943	14·4	1·02	14·69
1944	16·6	1·06	17·60
1945	5·8	1·06	6·15
Average, 30 years	12·1	0·94	11·37

EVAPORATION FROM A FREE WATER SURFACE

In Comparison with Precipitation on the Dominion Experimental Farms in the Prairie Provinces

TABLE 11

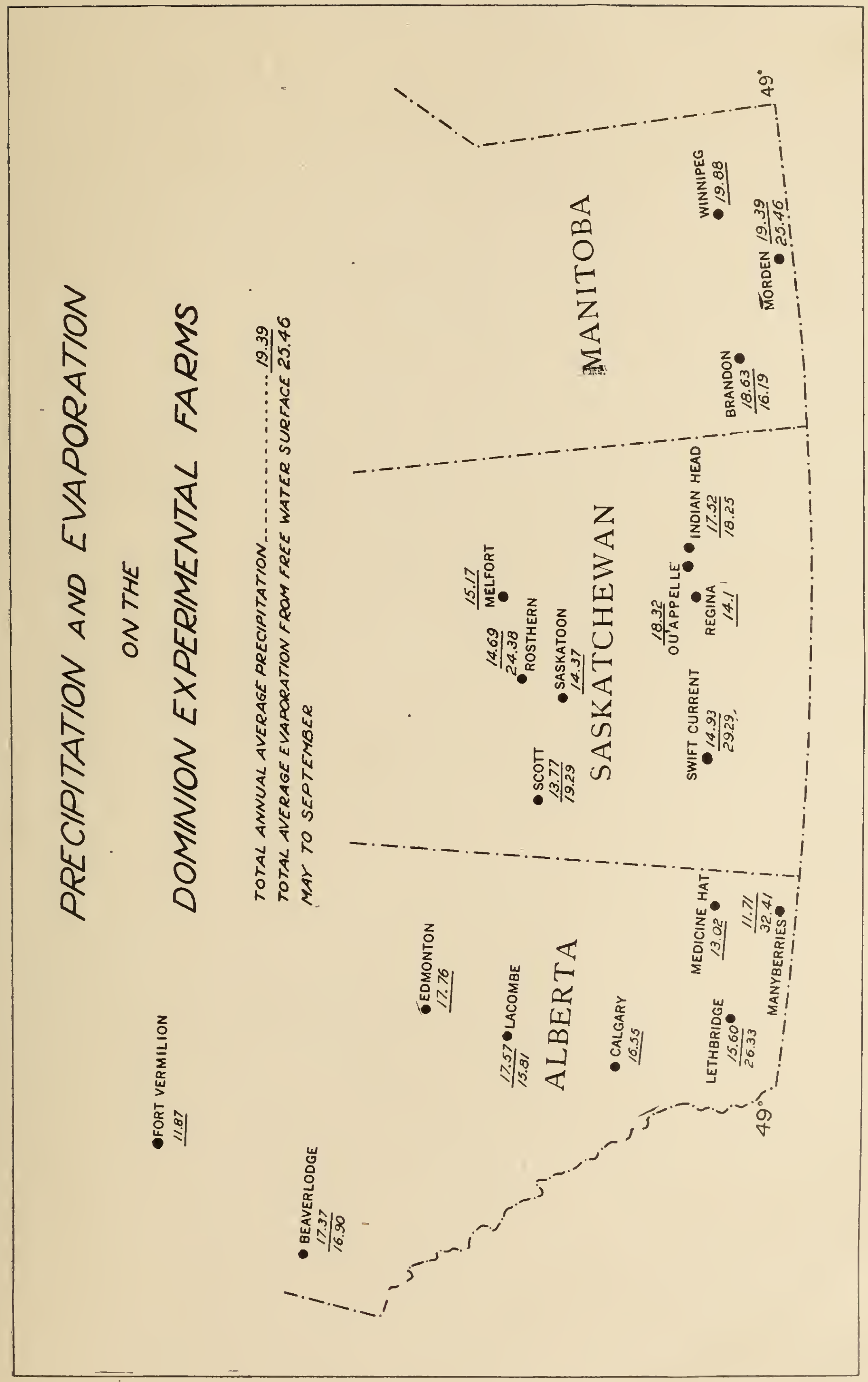
—	Precipitation			Evaporation	
	No. of years	Total annual	In 5 months May to Sept.	No. of years	In 5 months May to Sept.
		inches	inches		inches
Morden, Man	24	19·47	12·02	14	25·46
Brandon, Man	47	18·68	12·31	15	16·19
Indian Head, Sask	46	17·69	11·42	18	18·25
Swift Current, Sask	57	14·53	9·92	24	29·29
Rosthern, Sask	29	14·69	9·66	16	24·38
Scott, Sask	31	13·69	8·83	23	19·29
Manyberries, Alta	14	11·71	7·09	18	32·41
Lethbridge, Alta	41	15·76	10·13	24	26·33
Lacombe, Alta	35	17·35	12·05	23	15·81
Beaverlodge, Alta	27	17·55	9·51	24	16·90

The amount of evaporation at some stations is very much greater than at others, in some places being about twice as much. The ratio of evaporation to precipitation, either the total annual precipitation or that received in the five-month period from May to September is likewise very marked.

TOTAL ANNUAL PRECIPITATION AT REPRESENTATIVE POINTS IN THE THREE PRAIRIE PROVINCES

Table 12

Year	Winnipeg, Man. (60 yrs.)	Morden, Man. (43 yrs.)	Brandon, Man. (50 yrs.)	Indian Head Sask. (49 yrs.)	Qu'Appelle, Sask. (61 yrs.)	Saskatoon, Sask. (42 yrs.)	Scott, Sask. (34 yrs.)
	inches	inches	inches	inches	inches	inches	inches
1884	...	...	...	...	13·97	...	...
1885	...	...	...	...	11·92	...	...
1886	14·38	...	...	...	10·05	...	...
1887	17·93	...	...	...	14·48	...	...
1888	16·94	...	...	...	17·00	...	...
1889	14·95	...	...	...	10·54	...	...
1890	24·91	...	...	...	23·99	...	...
1891	20·09	...	...	...	19·02	...	...
1892	18·89	...	...	...	16·45	...	...
1893	23·93	...	...	...	16·35	...	...
1894	18·14	...	...	...	12·46	...	...
1895	18·42	...	...	...	15·29	...	...
1896	26·29	...	23·67	...	21·63	...	...
1897	17·59	...	13·37	20·72	12·64	...	...
1898	27·19	...	21·27	20·33	21·65	...	...
1899	19·82	...	14·50	13·54	19·27	...	...
1900	18·58	...	20·41	14·94	16·52	...	...
1901	23·90	...	18·69	26·92	26·47	...	...
1902	20·22	...	23·62	16·03	24·37	...	...
1903	16·92	16·56	19·69	19·00	20·09	...	...
1904	23·00	28·56	19·65	20·13	22·22	19·50	...
1905	19·90	28·29	20·60	22·82	24·55	10·85	...
1906	22·54	26·83	21·67	17·61	20·29	12·57	...
1907	16·88	12·61	17·38	18·15	18·53	10·38	...
1908	21·44	18·81	17·54	17·49	18·67	14·15	...
1909	23·12	18·00	18·86	19·37	25·75	15·87	...
1910	18·89	14·23	13·98	18·73	19·02	11·04	...
1911	23·38	16·18	20·53	23·69	20·61	19·45	...
1912	22·81	17·84	18·04	15·88	18·06	16·78	17·59
1913	15·78	13·20	12·89	23·98	21·18	13·45	11·34
1914	21·88	16·59	17·00	13·84	19·77	12·66	18·05
1915	16·97	15·34	16·01	16·15	18·67	10·50	10·46
1916	24·19	17·13	22·54	22·64	26·54	15·82	20·79
1917	13·76	12·36	11·31	13·84	16·69	12·74	7·37
1918	19·40	16·72	14·43	14·29	15·53	11·24	6·63
1919	25·13	24·91	17·17	17·53	17·92	11·59	11·18
1920	17·37	14·22	16·73	21·46	19·72	15·17	15·52
1921	22·03	23·06	22·62	25·01	27·19	20·82	13·48
1922	21·43	24·00	20·01	19·40	22·03	12·89	10·41
1923	15·70	14·50	18·01	25·68	27·05	18·73	15·02
1924	18·55	26·67	25·05	14·77	16·45	13·06	12·56
1925	16·09	21·17	19·06	16·80	16·70	16·41	16·85
1926	20·18	25·24	21·03	18·72	19·30	14·76	13·56
1927	21·45	12·31	24·13	22·89	25·55	21·28	14·89
1928	20·91	19·78	18·12	14·52	12·07	15·99	10·93
1929	14·32	14·41	15·08	13·46	12·05	11·99	9·97
1930	22·63	19·93	20·45	11·90	13·16	12·94	12·05
1931	16·92	15·82	14·82	9·14	10·72	13·70	12·60
1932	19·50	19·74	24·33	18·35	18·34	12·40	15·96
1933	20·31	18·80	19·55	20·61	19·25	12·88	14·57
1934	16·72	13·85	11·14	10·64	11·60	12·90	15·26
1935	23·19	21·60	26·50	21·52	23·15	17·56	15·13
1936	15·41	13·78	15·32	13·81	16·25	11·34	10·50
1937	19·82	25·03	24·76	10·32	10·54	10·74	15·64
1938	14·03	17·92	13·91	14·21	18·77	17·97	17·66
1939	16·50	15·58	14·33	12·44	15·53	15·75	14·00
1940	17·12	22·96	17·42	17·38	21·76	12·91	13·77
1941	24·50	23·41	21·53	15·07	15·01	10·34	13·88
1942	22·12	20·17	17·96	18·17	23·02	20·96	16·08
1943	19·83	19·22	14·52	14·58	19·36	13·52	15·06
1944	24·33	28·19	22·68	14·50	15·02	13·95	18·67
1945	22·72	19·41	18·15	15·46	...	13·91	10·81
Average	19·88	19·39	18·63	17·52	18·32	14·37	13·77


PRECIPITATION AND EVAPORATION
ON THE
DOMINION EXPERIMENTAL FARMS
TOTAL ANNUAL AVERAGE PRECIPITATION 19.39
TOTAL AVERAGE EVAPORATION FROM FREE WATER SURFACE 25.46
MAY TO SEPTEMBER
MANITOBA
SASKATCHEWAN
ALBERTA
WINNIPEG 19.88
MORDEN 19.39 25.46
BRANDON 18.63 16.19
INDIAN HEAD 17.52 18.25
QU'APPELLE 18.32
REGINA 14.1
MELFORT 15.17
ROSTHERN 14.69 24.38
SASKATOON 14.37
SWIFT CURRENT 14.93 29.29
SCOTT 13.77 19.29
MEDICINE HAT 13.02
MANYBERRIES 11.71 32.41
EDMONTON 17.76
LACOMBE 17.57 15.81
CALGARY 16.55
LETHBRIDGE 15.60 26.33
FORT VERMILION 11.87
BEAVERLODGE 17.37 16.90
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